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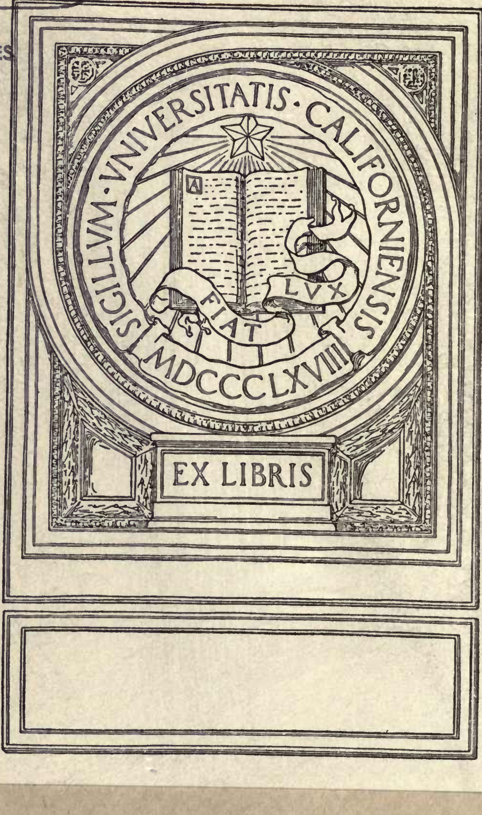
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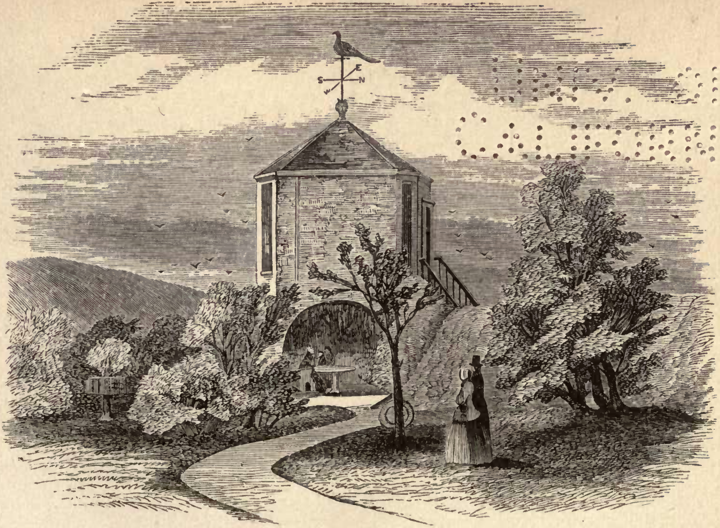

FRIENDSHIP GROTTO.

p. 9

MINERAL RICHES

OF THE

EARTH.

UNIV. OF CALIFORNIA

CAREFULLY COMPILED FOR THE AMERICAN SUNDAY-SCHOOL UNION, AND PROFUSELY ILLUSTRATED.

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PREFACE.

To every intelligent observer, the ground we tread on presents so much variety of substance that the mind naturally craves to know what it is made of and how it came there.

The following pages are designed in some degree to meet that desire and afford authentic information for popular reading.

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EARTH'S RICHES.

CHAPTER I.

SALT AND SALTS.

Mr. Goodman had a large family of sons and daughters, whose education he delighted to superintend; and young friends in abundance joined the social circle from time to time, sharing in their pursuits and partaking of their amusements.

As is common among intelligent minds, their attention was sometimes attracted to subjects which, for a season, engrossed all their leisure time; and one summer was very happily spent in constructing what they called "a friendship-grotto," inasmuch as the stones, minerals and fossils with which it was decorated were contributed by various beloved friends and relations, who kindly interested themselves in juvenile undertakings. Mr. Goodman was as zealous as any one; and, as his garden was situated among the inequalities of ground near a chain of hills, an appropriate spot was soon selected, where a sudden rising of the surface permitted the hollowing of a cave near a small spring of water. This cave was tastefully lined with specimens of all sorts. Stalactites hung from the roof; sparkling ores adorned the sides, with fossil woods, zoophytes and shells; and different-coloured pebbles studded the floor. A summer-house was built over the top, to which access was made by a gentle ascent behind the grotto, and here some glazed shelves and partitioned drawers received those fragile materials which could not be exposed to the air, or were so valuable as to be guarded under lock and key.

When all was completed, the interior of the grotto was furnished with a rustic table and seats; and it became the favourite resort for the solitary students in the family, or for the afternoon social gatherings, when in summer weather they loved to read and work together, and often refreshed themselves with fruit or tea, after their labours, in this cool retreat.

At length, when the excitement of building and the novelty of possession had in some measure subsided, and all their friends had duly praised the ingenuity and admired the results of the young people's handiwork, Mr. Goodman proposed that they should take occasion to derive some permanent advantage from the time they had so happily spent, and the presents they had received, not only from friends at home, but in foreign countries, of minerals peculiar to different localities and of widely different composition and use; for, till the subject is studied, few persons, perhaps, are aware how much their comfort and health depend upon substances composing the very ground they tread upon.

This proposition was hailed with general satisfaction; and Mr. Goodman, who had devoted much of his own youthful leisure to mineralogy, and had lately been watching for an opportunity of imparting some of his taste to his children, at one of the evening meetings for tea entered upon the subject by asking which of the objects around should be first discussed.

Edward Goodman, the eldest son, referred to salt, coals and metals, as certainly very useful, and his sister Alice to clay, earth and gravel, as necessary for the growth of fruit and vegetables.

Mr. Goodman said that it would help their memories to classify the subjects, and that, as they had just been eating salt with their early spring radishes, he would proceed to discuss that first.

He accordingly stated that COMMON SALT has some very remarkable qualities. It is a great preservative against the putrefaction and decay of dead animals, yet is so injurious to living worms and snails that it speedily destroys and dissolves them. In moderation, it is needful with food; yet eaten in very large quantities it causes death, as an irritant poison, both to men and animals. It preserves plants and fruits when no longer growing, and yet is so mischievous to living vegetation that the most expressive mode of describing a fertile country abandoned to barrenness is to say, as the Scriptures often assert, "It is sown with salt." Thus, in the book of Judges (ix. 45) it is related that when Abimelech took the city of Shechem, he destroyed it, "and sowed it with salt" to render the ground unfruitful.

Salt must have been very anciently known to mankind. It was one of the original chemical deposits made in the ocean, and the earliest inhabitants of the East had access to it, in the form of rock-salt. It is mentioned in the earliest books of Scripture; and, in the law given by Moses, it was prescribed to be mingled with the Jewish sacrifices. A store of salt was kept in the Temple, in an apartment appropriated to that purpose.

According to Oriental usages, to partake jointly of salt was a pledge of peace and friendship: so that when once shared, even unwittingly, the bitterest foes were safe from mutual injury. This accounts for the phrase, frequent in Eastern tales, "He has eaten salt with him;" and the same meaning belongs to the Scripture expression "a covenant of salt." The bond of friendship and reconciliation was renewed by each fresh sacrifice under the Jewish dispensation. "Neither shalt thou suffer the *salt* of the covenant of thy God to be lacking from thy meat-offering." (Lev. ii. 13.) "It is a covenant of *salt*," or friendship, "forever." (Num. xviii. 19.) "The Lord God gave the kingdom over Israel to David by a covenant of *salt*." 2 Chron. xiii. 5.

We now no longer need the symbolic salt in our approaches to God's mercy-seat, because we are told in the New Testament that Jesus has offered himself a sacrifice for all sins, and is now the perfect Intercessor and Mediator for all who by faith come unto God through him.

Alice inquired whether the phrase in English history, "sitting below the salt," meant the same thing as the Oriental pledge of friendship.

Mr. Goodman answered that that refers to the olden time, when a chief, and all his household, dined at the same table, but he and his family and guests sat at the upper end, above the salt-bowl, which was usually placed in the middle: hence to be *above* or *below* the salt indicated the rank of the person so seated.

It is supposed, from the descriptions of Herodotus, that the ancient Abyssinians used to enclose their dead in masses of rock-salt, which is very common about that part of Africa. It is still employed as money there, and also in Thibet. The slave-caravans across the deserts of Northern Africa carry rock-salt in great cubical masses as merchandise.

Salt is very extensively distributed both in the Old and New Worlds; in some regions in its fossil state, as rock-salt; in others, in brine lakes or springs, and thin incrustations formed by evaporation through the sun's heat. Wherever the sea comes, people may, if they choose, get its salt, by boiling and evaporating its waters. This process, however, yields but a coarse-grained kind, needing much purification, so that it is generally abandoned as civilization advances. The Turk's Island salt is of this kind. Many countries depend entirely upon foreign supplies of salt, and it is then an expensive article: in India fifty cents a pound is no uncommon price. Salt has been sometimes so heavily taxed as to occasion much distress among the poor.

Salt became excessively dear during the war of the American Revolution. In a few places the inhabitants procure all their salt from the ashes of vegetables. The annual production of the English mines, from which the Western world is largely supplied, is about five hundred thousand tons, most of which comes down the river Weaver to Liverpool. The annual consumption of salt by an adult man or woman has been estimated at sixteen pounds.

Edward here interrupted to ask if all sea-water contained the same quantity of salt.

Mr. Goodman told him that it varies considerably. The water of the Baltic Sea is reckoned to contain one-sixty-fourth of its weight of salt; that of the sea between England and Flanders, one-thirty-second; and the sea-water on the coast of Spain, one-sixteenth of its weight; and it varies again elsewhere.

In the heart of the American continent are extensive deserts and lakes of salt water, the largest of which is Utah Lake. Such exist also in Chinese Tartary.

It is a rule in geography that whenever a body of water has no outlet to the sea it must be salt, because its rivers are always bringing down salt from the rocks around. The ocean is salt, because it necessarily retains all the salt that flows into it. Bodies of water like the Dead Sea, which lie low and under a hot sun, are necessarily salter than others. Salt water also being heavier than fresh water, the bottom of the Mediterranean Sea is salter than the top. This has been tested by experiment. At a depth of six hundred and seventy fathoms the salt water was found to be four times as heavy as at the surface.

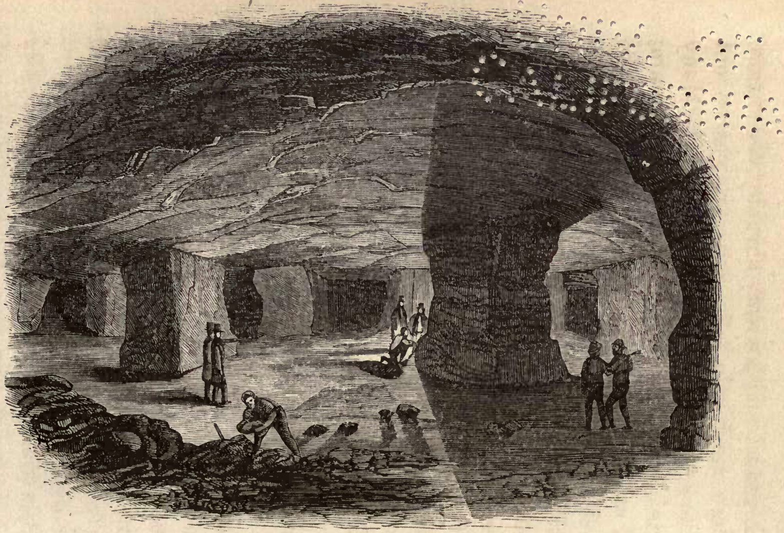
Salt seems quite a necessary of life to human beings; for we put it into all our food, while in nature it occurs in milk and other substances. Almost all graminivorous animals are fond of it, and a mixture of it in their food seems beneficial. The wild animals of the forest repair regularly to the salt-licks, where salt waters issue from the rocks and form pools or marsh places, and here the hunters lie in wait for them. Some are called deer licks, others bear licks, and others buffalo licks. Regularly-beaten tracks or paths descend to them, which have been used by the animals from very ancient days, and form the best ways to cross the mountains. In similar licks the mammoths and mastodons of old were frequently mired and lost, and their skeletons are found at the present day. All animals need salt in some measure. It is, however, said to be injurious to poultry; and if human beings feed too much upon salt food, they suffer from scurvy and similar disorders, while the drinking of sea-water has often caused madness and death. The prophet

Elisha healed waters by casting salt into them; which seems strange, for salt water is not fit to drink, and does not generally improve the land. But perhaps a remedy apparently so unlikely may have been commanded by God as a clearer exercise of his miraculous power.

There is more in the Bible about salt than many might suppose. It is mentioned as a familiar substance in the book of Job, (vi. 6,) one of the earliest known records. "Salt-pits" are named by Zephaniah, (ii. 9,) as well as "the city of salt" by Joshua, (xv. 62.) The "valley of salt," (2 Sam. iii. 13,) "a salt land," (Jer. xvii. 6,) "salt marshes," (Ezek. xlvii. 11,) and a "pillar of salt," (Gen. xix. 26,) are all spoken of in the books of Moses, Samuel and Jeremiah. All the various modes of procuring salt seem thus early to have been in use, while its common abundance is still further shown by Ezra's statement (vii. 22) that King Artaxerxes directed his treasurers to supply for the temple at Jerusalem "salt without prescribing how much."

Salt was valuable enough to bear a tax in the time of the Maccabees, as it did also in the reign of Ancus Martius, the fourth king of Rome, B.C. 640; and the Romans took tribute from the Droitwich mines, in England, from their first settlement, paying their soldiers partly with *salt.* Hence, it is said, we derive our word salary (from *sal*, salt) for the payment of work.

These Droitwich springs are mentioned in Doomsday Book, and are yet inexhaustible, rising from beds of solid rock-salt through strata of gypsum from one hundred and twenty to one hundred and fifty feet thick. The salt-mines at Northwich, in England, are two hundred and twenty feet deep, lying in two beds, alternating with gypsum and marl. The salt-rock is red, and so hard as to need gunpowder. In the eastern part of France beds of rock-salt have been discovered, lying in regular order over one another, like beds of coal, to a great depth in the ground. The borings through these beds, by which the salt water is allowed to ascend to the surface, are one thousand feet deep. The salt-wells of Syracuse, in the State of New York, sink to masses of rock-salt in a very ancient formation, which contains also gypsum; and gypsum and salt usually go together in geology. At Saltzburg, in Southwestern Virginia, there is a deep valley filled to the depth of five hundred or one thousand feet with red clay, gypsum and rock-salt; and all that part of the country is now supplied with salt from thence. The hundreds of salt-wells sunk during the last fifty years along the valleys of the Monongahela, Youghiogheny, Conemaugh, Alleghany, Beaver, Muskingum, and Mahoning Rivers in Western Pennsylvania and Ohio, and along the Big and Little Kanawha and Sandy Rivers in Virginia and Kentucky, descend through the rocks of the coal-measures and obtain their salt water from the formations immediately underneath, where lakes or sheets of it exist in the bottoms of the basins. When this salt water ascends to the surface, through natural crevices or through artificial auger-holes, it is often accompanied with coal oil and coal gas; and these valuable natural products of the earth are sometimes used to boil the salt water at the mouth of the well. It does not follow that all salt springs must be at the level of the ocean, although they must be in the bottoms of valleys; for the salt lakes of Utah are in valleys elevated many thousand feet above sea-level. The central parts of the continent consist of elevated plains, covered [illegible] and those valuable natural products of the earth are sometimes [illegible] the salt [illegible] the [illegible] of the soil. It [illegible] [illegible] of Hindu [illegible] and [illegible] The [illegible] of the continent [illegible] elevated plains, [illegible]



SALT MINE.

Opp. p. 21.

with gravel and a scanty shrubby vegetation. Where much rain falls, salts are washed out of the soil, and vegetation is abundant. Many parts of the world are barren for want of rain, and are very salt. The Isle of Ormus, in the Persian Gulf, consists almost entirely of rock-salt. There is no sweet water, nor grass; and, though once a place of trade for the Portuguese and Persians, it is now almost deserted, as it produces nothing but fine white salt. This sometimes lies two inches thick upon the ground.

Perhaps the largest salt-mines in the world are those of Cracow, in Poland, extending nearly a league under ground. Many of the workmen and horses live there entirely. There are cottages and chapels, statues and crucifixes, before which lamps are kept continually burning. When well lighted up, these lamps look very glittering and beautiful, as the crystals reflect the light in splendid coloured rays.

Sacred history informs us that, as the family of Lot were fleeing from the doomed cities of the plain, his wife "looked back" and "became a pillar of salt." That an object has been seen which was said to be the pillar into which Lot's wife was turned, and which the beholders believed to be such, there is little doubt. In one of the Apocryphal books allusion is made to the destruction of the five cities:—"Whose land, for a testimony of their wickedness, is desolate and smoketh to this day, and the trees bear fruits that ripen not; and a standing pillar of salt is a monument of an incredulous soul." This passage might be sufficient for the faith of Roman Catholics, but would have no weight with Protestants.

That a column of solid salt should be found in a region where there are "precipices of pure crystallized fossil salt forty or fifty feet high and several hundred feet in length,"* is by no means incredible; but there is no satisfactory evidence of the existence of any visible memorial of the judgment which came upon Lot's wife.

Indeed, it is remarkable that the scenes and events which the sacred history records should be so rarely marked by permanent visible monuments. To those who receive the Sacred Scriptures as of divine authority, their testimony is conclusive. "If they hear not Moses and the prophets, neither will they be persuaded though one rose from the dead."

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* Dr. Robinson, edit. 1841, vol. ii. p. 482.

Rock-salt is generally either of a pale red, green, blue, gray, or yellow color, and requires purifying to assume the delicate hue suited for domestic use. Only small cubes here and there are white. It is purified by dissolving the rock-salt in water, or by boiling the brine from the salt springs over and over again, and evaporating, or suffering the water to fly off in vapour. The salt liquor is generally boiled in large shallow vessels, and the salt continually stirred, to prevent it from crystallizing as it granulates. It is afterwards dried, and sold in cakes of convenient size.

Salt could be made in the chemist's laboratory if it were worth while to do so; but it is too abundant in nature to need artificial production. Chemically, it is a chloride of sodium. It used to be termed muriate of soda, but according to more accurate modern nomenclature its proper name is, as stated, chloride of sodium. There is generally a sediment, or residue of insoluble matter, from most brine. Salt prepared from sea-water leaves a mixture of carbonate of lime and carbonate of magnesia, with fine flinty sand. Rock-salt generally leaves sulphate of lime, (gypsum,) or some sort of marly earth.

Salt water does not generally freeze so soon as fresh water: it requires a greater degree of cold to produce ice. Yet the arctic regions afford abundant proof that it freezes very completely under severe cold; and salt is added to snow and ice by confectioners to quicken the process of freezing their creams. In the salt steppes of Orenburg there is a remarkable cave, called the Freezing Cave, from the fact that during the summer months the surrounding region of salt renders its atmosphere so cold that snow and icicles line it at that season,—though in the winter the same cave is so much warmer than the external air that the Russians state they could sleep in it without their sheepskin cloaks.

There is a coarse-grained salt that fishermen use for salting fish, known also to most housekeepers by the name of bay salt, which is merely salt less carefully stirred in boiling and purifying than the finer sort. Both that and the finer kinds equally preserve fish or meat; but for packing and exporting such provisions the larger grains are best, as they do not soon dissolve, and therefore melt only as the juices of the meat absorb them. Bay salt is thus exceedingly useful for long voyages, and, moreover, is used for preserving foreign skins during their travels to the tanner. Great quantities of salted hides are brought from South America. Damask roses, too, are imported for the chemist and perfumer, mixed with salt, which does not affect their sweet scent in the least: indeed, much of their colour is retained, as may be noticed when making rose tea from the chemist's stores.

From the earliest periods, salt was used for preserving the bodies of animals; and even the corpses of men were placed in salt or brine when removed to any distance for funeral rites. Pharnaces, the unnatural son of Mithridates, King of Pontus, not only joined the Romans against his father, but, after procuring his death, sent the body packed in salt to Pompey at Rome. In the fifth century, the monks were accustomed to preserve the heads of martyrs in salt; and animals for zoological collections were successfully kept in brine for a long period. Of course, butterflies and birds would lose the beauty of their down and feathers in brine: they would recover their proper looks after being wet.

Soda and muriatic acid are both extracted from this useful mineral. Salt thrown into the oven where common pottery is baked produces a glaze upon it. It improves the whiteness and clearness of glass, gives hardness to soap, and is used both in melting metals and dyeing calicoes and stuffs. It quenches flame, and is therefore useful to stop a chimney on fire; while wood thoroughly steeped in salt water is very slow to burn. Nor is this all. Salt-water baths are often recommended to strengthen weak limbs; for salt purifies the skin, and, by producing a gentle irritation, increases its healthy action. Some of the salt may also penetrate the pores, so as to mix with the blood and supply any deficiency there.

The young people looked so surprised at this statement that Mr. Goodman explained that salt should be in the blood of most healthy animals, mankind included. Dr. Livingstone perceived the salt taste even of fresh animal food, after he had long been deprived of it; and the absence of salt, which it was sometimes difficult to procure in the interior of Africa, created an intense longing for meat or milk, the salt in either of which seemed to supply the want in a great measure. Most people can remember noticing a very salt taste when the mouth bleeds at all copiously, and are surprised when the doctor says that it is all right.

Salt, though rather painful when applied to a wound, does not really do mischief, but frequently promotes its healthy healing. The writers of the New Testament often use salt as an emblem of wisdom:—"Let your speech be always with grace, seasoned with salt;" and of purification, "Ye are the salt of the earth," while consistently spreading a useful influence; "but if the salt have lost its savour," if professed Christians yield to the corruptions of the world, they lead others astray, and thus diffuse evil instead of good; and our Lord adds the fearful doom, "it is thenceforth good for nothing but to be cast out."

Many other substances are called salts, such as alum, borax, soda, nitre and saltpetre,—which, however, are seldom found in a native pure state, but are obtained from various clays and earths in which they largely mingle. Borax is found in the East and in South America, and is much used as a flux for melting and purifying various substances, and in soldering metals. Saltpetre is obtained from

Bengal, and is used in making gunpowder, signal-lights, dyeing, purifying metals and curing meat. Nitric and sulphuric acids are both procured from it, which, together with nitre itself, are largely used in medicine, though they are both poisonous, and, applied outwardly, rapidly corrode and consume the flesh.

Chloride of lime is a salt of rather recent discovery, and, in solution, is particularly valuable for its disinfecting properties, rendering a foul atmosphere speedily pure. Hence it is much used in hospitals, and in cleansing drains and places which generate unwholesome and disagreeable effluvia. It was discovered by Sir Humphry Davy during his researches upon gases. Chlorite, the mineral from which the salt is extracted, is composed of multitudes of little shining spangles which fall to powder under the pressure of the fingers. It is of a greenish colour, and occurs in Germany, Switzerland, Sweden, Norway and Java, mingled with other substances, such as clay-slate and sulphates of iron and arsenic. Chloride of lime is much used as a bleaching-powder. The paper-makers boil their rags in it to render them perfectly colourless: "therefore," said Mr. Goodman, "your pretty new print dress was spoiled by some being spilled on it, as well as the damask curtains."

He further remarked that all through the works of God in nature "one thing seems set over another:" there are antidotes to poisons, correctives of disagreeables, and promoters of all that is pure and pleasant,—reminding us of the power of God's grace to change the vilest hearts and the most unholy tempers by the purifying influences of the Holy Spirit,—as the Apostle Paul teaches us in his Epistle to the Corinthians. After describing some of the worst of sinners, he exclaims, "Such were some of you; but ye are washed, but ye are sanctified, but ye are justified, in the name of the Lord Jesus, and by the Spirit of our God." 1 Cor. vi. 11.

The young people seemed so much interested in these observations upon salt, that Mr. Goodman determined, while sharing in their occupations, to avail himself of any circumstance which would introduce the study of kindred topics, knowing that formal lectures at set times are often forgotten, while the mind eagerly seizes and easily retains information upon the materials which employ the labour of the hands. His own mental stores and still lively taste rendered him a fountain of wisdom, which could be readily drawn upon at pleasure.

CHAPTER II.

METALS.

EDWARD considered himself "fond of experimental philosophy." Alice used to laugh at him for possessing what she called "a genius for tinkering;" and now and then she laughed with good reason, for, in his great zeal for experiments, he did not always prove himself a prudent philosopher. He had visited some metal-works; and, interested with the various processes he had witnessed of casting, welding and hammering, he bethought himself of some lead he possessed, and fancied he could cast it into shape and impress upon it sundry devices, which would look much prettier than a plain mass of dull metal.

To work he went, and was busily occupied all one holiday morning, moulding, casting and stamping to his heart's content. But, alas! when he came to exhibit the result of his skill, his father looked grave, for the young metallurgist had used a silver half-dollar and some foreign silver coins for his dies, and they were much injured by the process. Edward could not tell why the real coins looked black, and asked the reason.

"Because," replied Mr. Goodman, "the surfaces of your silver coins have *amalgamated,* that is, united with the lead. You should not venture on such an experiment as this without knowing a little about the chemistry of such combinations. That black tint is actually the lead, which has mixed with the silver and alloyed all the surface. No common rubbing with plate-powder or leather will restore them. You cannot get rid of the lead till you grind down to a new surface, and the coins will then have lost some of their silver and be so much less valuable. Lead and silver are almost always found together in mines; and it is always a troublesome business to separate them."

"Well," sighed Edward, "I must keep my half-dollar, then, as a monument of my foolish ignorance."

"If you preserve it as a reminder to consider before you act, it will purchase you many a half-dollar's worth of wisdom, both in intellectual pursuits and moral actions: so you need not sigh too heavily over the loss of your money."

"But, father, will you tell me a little about metals? I never thought of silver and lead mixing together, as I found this morning they will do."

"You forget, then, the preparation of the metallic compounds you saw at Chicopee, when they were mixing bell-metal, queen's metal, pewter, pinchbeck, brass and bronze?"

Alice and the rest of the family here joined them, and, as they had watched Edward's experiments, they were curious to know the reason of the failure he lamented; and their father led them to the grotto, that he might be able to illustrate his remarks on metals by reference to the numerous ores they had there interspersed about the walls.

Mr. Goodman, looking more particularly at Edward, remarked that all METALS cannot be mixed together; but new compounds of metal are frequently invented, consisting sometimes of two only, and sometimes of several, in various proportions, according to the quality desired. Thus, copper and tin form not only bronze, but bell-metal; tin and lead make pewter; and small quantities of bismuth, zinc, or other metals added to these will produce considerable change either in appearance or quality. *Fusibility*, or the capacity to melt, is a very important and useful quality common to all metals in different degrees, as well as *malleability* and *ductility*, or their capacity for being beaten or drawn out, rolled into plates, bars and wire. All metals, too, have some degree of shining hue, termed the metallic lustre. They are not generally transparent, though, as leaf gold when held up to the sun transmits a green light through it, and silver a white light, it is probable that other metals might, if equally thin, also be thus partially transparent; but few of the other metals will bear being so much beaten out.

No metals have ever yet been decomposed, or divided into simpler substances, but are already what chemists call *elements* in their simplest state. There are several theories of their formation, each of which presents part of the truth. One theory supposes that metals have been deposited from above, by earthy or metallic salts held in solution by water, just as the mineral waters of the present day contain iron, copper, lead, &c. This is undoubtedly true of many mineral veins, as may be shown by their being composed of regularly-deposited linings of ore and spar on their walls. Other persons have fancied that the metals were the result of sublimed vapours or exhalations, as the mercury seems to be in the mines of Austria; and some again prefer to consider spars and metallic ores as injected, while melted by heat, into these veins. Electricity or magnetism seems to have contributed to the formation of metals,—either the general magnetism and electricity of the earth, or local currents of such forces, produced by surrounding influences. All metals crystallize into definite forms, and some into more than one form.

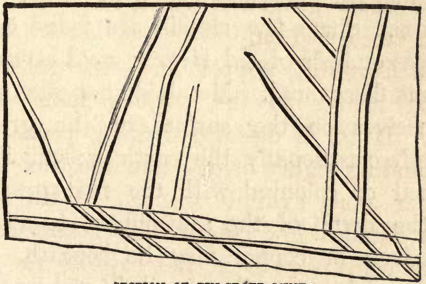
This question, as to how the metallic ores were formed, or, more properly, how they were deposited, is one which naturally rises in every thinking mind, and is frequently asked by those who examine collections of ores; for metals are scarcely ever found in a native or pure state, but are mixed with a great variety of mineral substances. Inquiring minds are trying to ascertain the cause of the metallic deposits, and the mode of their accumulation; but, though many interesting and ingenious theories have been devised and many curious facts discovered in the course of inquiry, no entirely satisfactory answer has yet been found. It is most probable that the metals were made with all the other chemical elements of matter when the world was created; for tin, iron, copper, chrome, cobalt, manganese, titanium, arsenic and one or two other metals have been detected in the oldest rock formations with which we are acquainted. Yet there are many metallic veins or streams of ore, which have evidently been deposited during convulsions of nature of a much more recent date than the geological age of the rocks in which they are found. Such are the copper veins of Lake Superior, and the tin and copper veins of Cornwall. They vary greatly in width,—the Cornish veins from one inch to thirty feet. In other countries much wider veins occur; but even the narrow veins are often rich enough to be quite worth working, especially as they are so very deep that they have never yet been fathomed, or exhausted of their contents, even three thousand feet below the surface. The lately-discovered Washoe silver vein, on the west coast of North America, worth from three thousand dollars to nine thousand dollars a ton, is only eight inches wide. The great iron-ore bed of Marquette, in Michigan, is one thousand feet wide. In following the course of veins, they are generally observed to slant downwards from the commencement. Sometimes they widen as they are explored, and a large deposit is reached, whence several veins seem to have started. Other veins become narrower, descending, and stop altogether; or spar, or some other material, is substituted for the metallic deposit.

In the earliest records of man, frequent mention has been made of metals. Even in the description of the garden of Eden, gold—good gold—is particularized; while Job says, "Surely there is a vein for silver, and a place for gold in the earth. Iron and brass are dug out of stones," (Job xxviii. 1,) suggesting the idea that mining-operations were known from the first. Indeed, Tubal-cain, the instructor of workers in brass and iron, lived *before the flood.* Gen. iv. 22.

These metallic veins are generally enclosed between hard, dark-coloured crusts, which miners term the *walls* of the vein. There is mostly, too, a small vein of a whitish clayey substance running down one or other of the walls. Besides this, most metallic veins contain a good deal of spar and quartz, either loose or crystallized against the sides. Occasionally large empty spaces occur, lined with beautiful crystals. Experience, of course, in some degree enables miners to learn from appearances whether the veins are likely to continue to bear metal or not; but these appearances are often so fallacious that mining is at all times an uncertain experiment. It is also hazardous and costly, from the great depth under ground at which the work must often be carried on.

In Cornwall, copper and tin are seldom found nearer to the surface than eighty feet. If tin is discovered then, perhaps, in descending eighty or one hundred feet lower, copper alone exhibits itself; but tin is seldom found below copper. In Tennessee, the black copper-ore is at the base of the hills, and under it the veins are a poorer mixture of sulphur, copper and iron. Another difficulty arises from a second system of veins of a totally different metal often crossing the first and altering the direction of the east and west veins, "heaving them out of their course," as the miners say, sometimes one hundred or even five hundred feet north or south of their true place, so that they can be found again only after long, laborious and expensive search: in one case forty years have been thus occupied. In many districts these *heavings* happen several times to the same veins, to the exceeding perplexity of the workmen, especially when numerous veins thus cross each other.

At the point of crossing there is generally a considerable change of composition in the contents of veins, so as to excite some expectation of a crossing vein. Indeed, the same mineral vein varies so much in passing through different sorts of strata, or layers of rock, that the miner looks for a change of metal with every marked change of ground or "country."



SECTION OF TIN-CROFT MINE.

In Cornwall, the copper-ore of a vein passing through clay slate becomes richer on entering granite, or, what is more remarkable, produces copper-ore differently mineralized. In the Lake-Superior region, the veins—which all cross the rocks nearly at right angles—show an abundance of copper only while they are passing through sandstone, but become barren when they enter the trap. All metals are not found in these curious veins; for some are in large horizontal layers or beds; but these are generally the ores of iron, lead, zinc and manganese combined with other substances. Some few metals are found in the sources or beds of old rivers: gold especially is thus discovered. Metals do not often show themselves on the surface of the ground, though occasionally the earth is sufficiently stained or coloured with the rust produced by the damp of the atmosphere to suggest that iron or copper may lie beneath. The show which iron makes for itself and its allied metals is called its "gossan."

The beds of metal worked as mines are generally rather low; but all the best known silver-mines are situated in high table-land, which would not be inhabited but for the mineral treasures to be obtained. Thus, at Pasco, in Peru, there are silver-mines with some thousand mouths opening into the very houses of the owners. A complete network of silver veins appears to spread there beneath the surface of the earth, one of which is nine thousand six hundred feet long and four hundred and twelve feet broad. Gold is frequently found near the surface of the ground. The Gold Coast of Africa is so named from its abundance in the sands. The gold-fields of Peru, California and Australia occasionally yield large nuggets, or lumps, of the precious metal, weighing several ounces and even many pounds; but they are remarkable and rare. Gold occurs in every quarter of the globe, and nearly in every country, though not always so plenteously as to be worth the expense of digging for it.

"What! Is there gold in Vermont and Massachusetts?" exclaimed Edward and Alice both together, in amazement.

"Yes; and in Virginia and North and South Carolina and Georgia also," said Mr. Goodman. The United States Government has an assay-office in North Carolina for the native gold. The Dahlonega and other mines there are very rich, and the new hydraulic process of washing out the gold and gravel by tearing the hills to pieces with tremendous jets of water brought in canals and pipes for many miles, which has revolutionized gold-mining in California, is now being introduced into the Carolina gold-fields with great profit. Almost every river which flows into the Atlantic brings down small quantities of gold. But the Rocky Mountains seem to be the home of gold, from which, in the future, the world is to be supplied. It is a proof of God's superintending care that the most useful metals—gold, silver, iron and copper—are freely distributed all over the world, and generally in situations that can be got at without much difficulty: hence, throughout history they are continually named as substances of common use. Lead and tin are abundant in certain localities, where they were discovered in very early times and imported to other countries. Both were known to the ancient Egyptians. The Cornish tin-mines, in all probability, supplied the luxurious city of Tyre, (Ezek. xxvii. 12;) but the tin found among the six varieties of metal in the spoils of the Midianites by Moses may have come from the East Indies. (Num.

xxxi. 22.) The lead-mines of Derbyshire (England) were worked long before the Roman invasion; but lead was used as a writing material in the time of Job, (xix. 24,) and its great weight was remarked by Moses, when he sang at the Exodus, "They sank as lead in the mighty waters." Exod. xv. 10.

Quicksilver or mercury, antimony, zinc and platinum, are seldom found in their metallic state, but are extracted from their ores by various laborious processes; while the metals forming the bases of several metalloids—aluminum, silicum, sodium, &c.—are never procured except by artificial means, and then some of these are so quickly changed by the influence of the atmosphere that they are only slowly coming into use in the arts, and chiefly in the form of alloys.

You are familiar with gold and silver money, silver spoons, copper tea-kettles and coal-scuttles, steel pens, tin saucepans and dish-covers; but perhaps you have not thought of many other metals and their uses. There are at present known about fifty-one distinct metals, which cannot be decomposed. Some of these have been only discovered so lately that we may suppose other unknown ones still to exist; and they are separated from their ores in so many different ways that I cannot describe all very particularly.

Native gold is procured by simply washing and picking out the glittering particles from the earth or sand amidst which it lies, or the quartz rock in which it lies is picked and blasted, broken up and crushed with hammers and wheels, and mixed with mercury in pans full of water. The water flows off and leaves the amalgam of mercury and gold. Afterwards the mercury is driven off in vapour by heat, and the gold remains pure behind, only containing here and there small, sharp and exceedingly hard crystals of osmium, iridium and rhodium, which are picked out at the mint and sold to make the diamond points for gold pens.

The amalgamation of silver with mercury in South America is effected by the trampling of horses, but the quicksilver soon destroys their hoofs, and in a very few years they are unfitted for work. Gold and silver are too soft for use as money without an alloy of copper; they are not only used for money and for ornament, but, as ordinary acids do not injure them, they are employed for spoons, ladles and other domestic articles. Silver, especially, is common for such purposes, and it was thought that aluminum, or clay metal, which is as white as silver but only half as heavy, would be used for the same purposes; but it rusts too easily, and is very hard to work, so that it is only used as an alloy. Gold and silver make beautiful colours also, and are therefore used in colouring glass and china-ware.

Silver combined with nitric acid produces the caustic of the surgeon; while the addition of sap green, or Indian ink, forms marking-ink: when alcohol is added, fulminating powder is the result,—an exceedingly dangerous compound, which explodes with a very little heat or friction. This powder is used in making lucifer matches, percussion-caps, Congreve rockets, and such things.

A little silver is occasionally found in quicksilver-mines, but mercury seldom lies in silver-mines. It occurs mostly in chalk or clay rocks, sometimes in pure globules, but more commonly as an ore with sulphur, called cinnabar, from which it is driven off as a vapour by heat. It derives its name of "quick" or living silver from its usual fluid state, the movable globules continually eluding the touch, as if it were alive. It is usually carried either in iron or glass jars, leather bags, or bamboo canes. Pliny mentions that the Greeks obtained cinnabar from Almaden, in Spain, 700 B.C., and that the same mines in his own time yielded annually seven hundred thousand pounds. Quicksilver is still derived from them, and their present annual product is nearly three millions of pounds: so that during the last three thousand years they must have yielded an immense quantity.

There are some quicksilver-mines also in Peru and in China. Mercury was discovered at Idria, in Austria, about 1497, in rather a singular manner, which shows the importance of noticing facts occurring in daily life, and thinking over any unusual circumstance. The district at that time abounded in wood, and was chiefly inhabited by coopers. One evening a cooper placed a new tub under a dropping spring, to try if it would hold water, and the next morning he found it so heavy that he could scarcely move it. At first his superstition led him to think it was bewitched; but, perceiving a shining substance at the bottom, he collected and carried it to the town, where it was soon ascertained to be valuable mercury. His profits from the sale of his treasure resulted in a successful search further for the metal.

Quicksilver-mines are unhealthy for the work-people, not only from their heated atmosphere, but from the danger of imbibing the poisonous mercury itself into the system through any little scratch, or with food. The Austrian mines are used as a place of punishment for state criminals. In 1810, some ships were bringing home a cargo of mercury from Cadiz, when some of the bags burst and the contents were spilled. All the copper articles on board speedily became amalgamated: rats, mice, cockroaches, a canary-bird, fowls, dogs, cats, sheep and goats were destroyed, and the whole of the crew were seriously ill: indeed, two of them died.

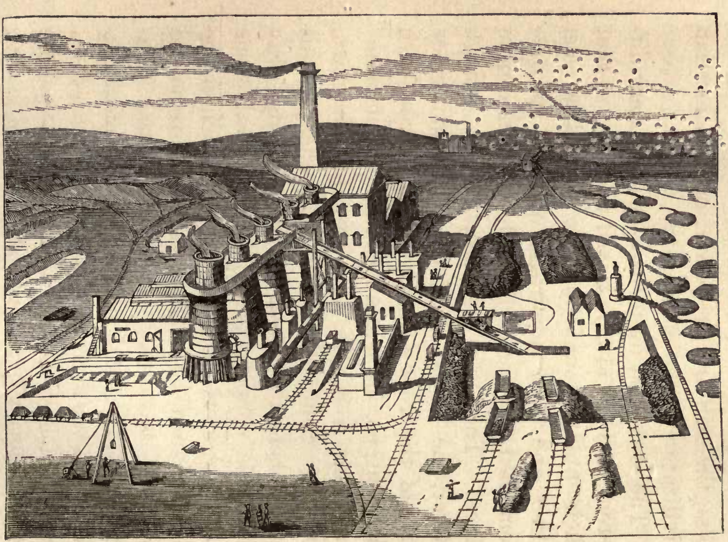
Quicksilver is a difficult metal to use in the arts on this account, and, even with great care, our mirror-makers are liable to a disease called "the shaking palsy." It loosens the teeth, causes the hair to fall off, and produces great pain and softness in the bones, which is greatly aggravated by damp weather. As calomel, it is used in medicine, but great caution and medical advice are requisite in taking it. The brilliant red paint called vermilion is produced from mercury. Corrosive sublimate is another exceedingly dangerous preparation from it, used for preventing dry-rot in timber and mildew in sail-cloth.

Mercury is never seen in a solid state, except when frozen solid in the coldest arctic regions,—when, of course, the philosophical instruments depending upon it are rendered useless. In these regions, the philosophers themselves have, for curiosity sake, shot bullets of quicksilver from their muskets.

"They told me," said Edward, "when I was travelling last summer up the Lehigh River, in Pennsylvania, that they made iron out of stone. What does that mean?"

Mr. Goodman then described the iron-manufacture, and began by saying that iron is never found in a pure state, like gold or copper, but only as ore, of which there are six principal useful varieties,—wanting a great deal of preparation before you could make out of them a spade or a needle. The ore, or iron-stone, as it is called, is first roasted, to drive off the water, sulphur and arsenic with which it is often combined; then smelted in a high stack-furnace with coal or charcoal, when the melted iron runs out from the bottom into moulds of sand or clay, where it is allowed to cool. The rough bars of cast iron are called "pigs," because they lie side by side along the casting-floor in the sand, all attached at one end to the great stream of metal down the centre, called the sow, which is broken up and smelted over again, while the pigs are heated and hammered into blooms or balls of wrought iron and then rolled into bars and sheets for use. Some of the pig-metal is re-melted and run into moulds of various shapes, to make castings of all kinds, pots and skillets, railings, columns for buildings, the bed-plates of engines, cannon and cannon-balls, car-wheels, and a thousand other things, both great and small.

An iron-furnace is a grand object. The largest sort are sixty feet in height, built up of solid masonry, like a square tower, with sloping sides, in every one of which is a great archway, and under each are pipes through which hot air is blown through holes into the raging fire within. Sometimes a single furnace-stack will have twelve of these nozzles blowing air into it at once. The nozzles, or "tuyeres," as they are called, are surrounded by cool running water, to keep them from melting. The air is heated in furnaces at the top of the stack, and driven forward by powerful steam-engines and great air-pumps of cast iron. The coal, ore and limestone are carried over high bridges from the hill-side to the furnace-stack top, to be thrown in at the "tunnel-head" or mouth of the furnace; or else are hoisted up in movable stages by the weight of water; or else are drawn up on long inclined planes by steam-engines from the banks of the canal or the platform of the railroad. Sometimes three, four or five of these great furnace-stacks are built close together in a row, and have one great top for all, on which the hot-air ovens stand, and along which the "stock" of ore, &c. is drawn on wheelbarrows. Tall chimneys rise from this high place still higher into the air, and perpetual flames and noxious gases pour from the tunnel-heads. At night the glare of the fires above, and of the molten metal below, the laborious sighing of the blast-pipes, the clanking of the hoisting-apparatus, and the rolling of the trains of cars bringing ore or carrying off the metal, make a scene which when once



PARKFIELD (ENGLAND) IRON WORKS

Opp. p. 51.

seen can never be forgotten, and is perhaps the best symbol of the energy and productiveness, the skill and the power, of the Christian civilization of the present day.

The ores used by furnace-men are very different, and are always mixed together, so that their hurtful qualities may neutralize each other and their admirable qualities may be combined in the cast iron which is made from them. Thus, for instance, on the Lehigh River, the heavy black magnetic and zincy ores of the New Jersey veins are mixed with the light, porous brown hematite or "limonite" ores dug from the pits around Allentown. On the Schuylkill and Susquehanna, this brown hematite ore is mixed with the gray magnetic coppery ore of the Cornwall mine near Lebanon. On the North Branch of the Susquehanna, both these varieties are mixed with the blood-red "fossil ore" of the Montour's Ridge, at Danville and Bloomsburg. At the head-waters of the Juniata, this fossil ore, again, is mixed not only with the pipe ore of the interior limestone valleys, but also with the carbonate ores or clay iron-stone of the coal-measures. At Pittsburg, and in Northern Ohio, these carbonate ores are mixed with the magnetic ore which comes in lake boats from Lake Superior and in steamboats from Missouri; and both these varieties are mixed, again, with "black band" ore, and soft outcrop brown hematite ore, found also in the coal-measures. Finally, the mixture is carried still further at some furnaces which stand in the neighbourhood of rolling mills, by adding what is called rolling-mill cinder, which contains a large percentage of iron.

Cast iron was unknown, but casting-in brass was common, in the days of Solomon, when vessels for the temple were "cast in the clay ground between Succoth and Zarthan," (1 Kings vii. 46,) and no doubt suggested the preacher's simile, "If thine enemy hunger, feed him; if he thirst, give him drink; for in so doing thou shalt *heap coals of fire upon his head*," (Prov. xxv. 22,) or melt him with thy kindness,—repeated also by the Apostle Paul. (Rom. xii. 20.) Perhaps Solomon used to watch the workmen smelting, and then God put the thought into his mind.

Iron is refined by being strongly blown into while in a melted state. This is called the Kelly process, and is in use in the Western States. When re-melted and blown into, according to Bessemer's process, it becomes excessively hot, and loses all its impurities, but is not so useful as when it has a small percentage of foreign matter left in it, which seems to give it fibre and strength. Small quantities of other metals, such as tungsten, are found to be beneficial also to its strength; but a small quantity of sulphur left in iron makes it very brittle when it is hot, so that it cannot be worked by the machinist or blacksmith; and small portions of phosphorus or silicon make it very brittle when it is cold. A small quantity of carbon or pure coal is mixed with iron at a slow heat to make steel, —which is much harder than iron. Pure iron, however, can be somewhat hardened by plunging it into cold water. The uses of iron have been thus well described:—"It can be cast into moulds of any form, drawn into wire of any desired strength or fineness, extended into plates, or beaten in every direction, and can be sharpened, hardened and softened at pleasure. Iron is equally serviceable to the arts, sciences, agriculture and war; furnishes the sword, the ploughshare and pruning-hook, the needle and graver, the spring of a watch or a carriage, chisels, chains, anchors, compasses, cannons and pens. It is a medicine of much virtue, —the only metal friendly to the human frame." Indeed, I do not know what we should do without iron, it seems a metal of such every-day importance. Steam-engines, bridges, ships, houses and churches are now made of iron, as well as innumerable articles of domestic use. Swedish iron is generally esteemed the best.

It is a singular circumstance that the only pure native iron which we are sure has ever been found has come from the sky, in the form of meteorolites, or stones which were wandering in space until they met the earth upon its way. Some of this iron has a mixture of nickel with it, and when polished shows a fine grain and shining hue nearly resembling steel, with curious markings called the Widmanstätian figures. The Esquimaux use this meteoric iron for their spears, and, indeed, possess no other metal. How this iron could drop from the skies has never yet been explained, and various theories are proposed, some supposing it to be ejected from volcanoes, others from distant planets, while some imagine it may be produced by some process in the atmosphere. Professor Shephard, at Amherst, in Massachusetts, has the largest collection of these meteorites ever made.

Plumbago has been considered a carburet of iron; but repeated analyses have proved that it contains so small a proportion of the metal that it must be looked upon as a sort of anthracite coal with iron occasionally present. It has never yet been either dissolved by acid or melted by heat, and therefore has not the true characteristics of a metal.

Loadstone, or magnetic iron ore, is a variety found in Norway, Cornwall and Scotland, China, Bengal, Arabia, Asia Minor and the United States, especially at Lake Superior, in Missouri, Northern New York, in the Highlands of the Hudson and New Jersey, and along the Blue Ridge of Virginia and the Carolinas. It is the richest and most valuable of all the ores of iron. It was known to the ancients, who ascribed medicinal virtues to it, using it for the cure of burns and weak eyes. The Chinese seem to have discovered its polarity and turned it to use as a compass long before the Europeans, and by them it was termed "the sailing stone." The ancient

Greeks called it the "Herculean stone, because it commands iron, which subdues every thing else." The loadstone not only attracts pure iron itself, but communicates its magnetic power to pure iron and steel when rubbed upon it: hence the magnetic needles used in the mariner's compass.

Arctic explorers have observed that the needle dips its north end more and more towards the earth as it is carried into higher and higher latitudes, until at last, at a certain point called the North Magnetic Pole, it stands vertical, and beyond that it points towards the south. The attraction of the surveyor's compass-needle for the masses of iron which are in the earth, renders it almost useless in surveying certain portions of the earth's surface,—especially in primary regions. It is used, however, for discovering the existence and locality of veins of iron-ore. The loadstone enables those who understand its use to astonish the ignorant by many amusing feats, which used to pass for magical wonders, such as "the enchanted swan, the mysterious watch," &c., by which a waxen bird appears to obey its master, or a watch to stop or go on at the command of its owner.

Among your toys you used to have some fishes that would have come to a magnetic hook.

Copper is generally found in brilliant ores, some of which are called Peacock copper. Copper pyrites look so glittering and attractive as to be called "fool's gold," because it has beguiled the inexperienced into fancying that a mine of that precious metal must exist in its neighbourhood. Copper is almost as useful as iron, not only in furnishing boilers, kettles and wire, but for sheathing the bottoms of ships, to protect them from the action of water and the attacks of sea-worms: it is also used to furnish green and blue colours to the printer. It combines readily with some other metals,—with zinc, forming brass and pinchbeck; with tin, in different proportions, forming bell-metal of varied sound, and also bronze. With tin and silver it makes a speculum metal, capable of receiving the highest polish, and used as mirrors for large telescopes; and, with tin and nickel, it forms German silver and other compounds of white metal for spoons, forks, teapots and other articles of domestic use. The oxide or rust of copper, however, is highly poisonous: therefore the old-fashioned custom of boiling a penny with greens, pickles and preserves, is dangerous. A copper-mine was discovered in Wicklow by a stream of blue water flowing from it, of so injurious a quality as to destroy all the fish in the river Arklow; and a workman having left an iron shovel in this stream for a few days found it encrusted with copper,—the copper thus obtained being of a purer quality than that produced by smelting, and the process a much less troublesome one.

The largest known copper-mines are in Sweden, one of which is twelve hundred feet deep, and its mouth so extensive, from having once or twice fallen in, that the visitor is a full hour reaching the bottom. Fires have broken out in it, and many passages are filled up to prevent their spreading; but the hot and sulphurous vapours are still excessively oppressive. This mine was anciently used as a State prison, in which criminals, slaves and prisoners of war toiled during their miserable lives; and here, too, Gustavus Vasa, disguised as a peasant, worked for his daily bread during a long concealment, after having been robbed by his guide; and it was well, perhaps, that he experienced some of the sufferings of his state prisoners. Much of our copper-ore comes from Chili, in South America, and a good deal from Eastern Tennessee; but the richest mines in this country are those of Keweenaw Point, on Lake Superior. Two millions of dollars' worth of copper-ore was sent from that region in 1859.

The famous malachite is an ore of copper found in the copper-mines of Russia, Norway, Wales, England and the Shetland Isles. Its beautiful colour, and the soft lustre which exhibits all its streaks, render it a pretty material for ornaments.

Mundic is another ore of copper, most abundant in Cornwall, where it was long considered of no use except to nourish the copper,—a curious miner's notion, which of course had no foundation. You have some cubes of mundic there; and the grain seems to be different on every side, so that if you were to cut through the cube you would cross the grain on its opposite side. The reason of this has never been explained, but it is one of its peculiarities.

"Was my lump of lead just as it came out of the mine, father?" asked Edward, looking ruefully at his workmanship.

"No," said Mr. Goodman; for lead also is almost always found as an ore, commonly mixed with sulphur; but there are fourteen or fifteen varieties occurring commonly in limestone. The most common and productive is *galena*, or sulphuret of lead. The carbonate of lead, a heavy white clay, is also greatly valued as an ore, and usually accompanies the sulphuret. The ores of zinc are almost always found in company with these ores of lead, especially in the limestone fissures of Wisconsin, Iowa, and Missouri. The ore is roasted and smelted in small open furnaces. Small cubes of pure lead are occasionally seen among crystals of lime in the Derbyshire mines. It is a soft metal, and easily spread into sheets for roofing, flooring, or for cisterns. River and spring water may be stored in these safely; but pure distilled water soon corrodes the lead, and dissolves sufficiently to render the water unwholesome.

Bullets and shot are made of lead, but it is mixed with arsenic to make it hard enough. Joined with tin, it forms pewter and soldering metal. With antimony and tin, it makes type and stereotype metal. Litharge, red lead, white lead and sugar of lead are all oxides, or rusts, of lead, employed as paints, or for making coloured glass, or for glazing pottery and enamelled vases. Lead pipe is now made by passing half-melted lead through a hole in the bottom of a reservoir, in which is a plug of iron of the size of the pipe-bore. The pipe as it forms is wound upon an immense drum, and afterwards cut into required lengths.

It is a pretty experiment to hang a small lump of zinc in a bottle, and then dissolve sugar of lead in water for making zinc trees. Little branches speedily show themselves all over the lump of zinc hung in the solution. Lecturers on chemistry often make this experiment, to prove the chemical affinity the zinc has for the lead; for those little branches are really the lead attracted from the water by the zinc, and thus deposited,—perhaps in some degree explaining how metals are accumulated in veins in company. Interesting changes are remarked upon coins that have been long buried in the earth, and in the metal utensils discovered in Assyria.

There are no true mines of zinc, but it is found in two ores, calamine and zinc-blende, in England, Germany, China and the United States. It requires all the processes of roasting, washing and smelting, and then rises as vapour to the top of large furnaces like glass-houses, and is conducted by tubes passing through water in small globules, which are afterwards melted together and cast into ingots for sale. It is, as you may suppose, a light metal, but, notwithstanding all this preparation, it is comparatively cheap, so as to permit its use for chimney-pots, water-spouts, roofing and flooring. It is quickly affected by acids, and is, therefore, not suited for use in the kitchen or dairy. Zinc plates are used for the transfer of printing, under the name of zincography. Joined with copper, zinc forms brass, as I mentioned before; and when plunged into sulphuric acid it is the powerful generator of electricity in the Voltaic pile battery. Zinc forms the other ingredient of the celebrated Franklinite iron-ore of New Jersey, and, by clogging the furnace-stacks and the burden of ore and coal, has proved a formidable obstacle to the use of that valuable ore in the iron-manufacture. And yet a small mixture of zinc in iron adds greatly to the toughness and strength of the latter.

Tin was one of the metals known to the ancients. You have some pretty specimens of tin-ore here, and minute grains of it are found in granite. It is mentioned by Moses (Num. xxxi. 22) among the six metals found in the spoils of the Midianites, which were to be purified from heathen idolatry *by fire.* As these Midianites were "merchantmen" trading with "pieces of silver" in Joseph's time, they doubtless traded also with "the strong city of Tyre" (Josh. xix. 28) of that period; and it is known that British tin was brought to Phœnicia, of which Tyre was one of the principal cities, in very early times.

Tin is by no means universally diffused, and in fact is a very rare metal. A small vein of it was discovered in the White Mountains of New Hampshire; but it has never been wrought. A valuable vein of tin-ore is reported as lately discovered on the western borders of Utah. There is a little tin-ore in Chili, Mexico and the East Indies, but it is abundant in Cornwall and Devonshire, England,—in two sorts of ore only, though occasionally it appears quite pure in small crystals. Indeed, block-tin is a collection of minute crystals intercepting one another in every possible direction, so as to leave tiny spaces between. Hence it is a light metal, and produces a peculiar crackling noise in bending, which the French call "*le cri de l'étain*," or "the cry of tin." Attention to the shape and direction of the crystals greatly assists the polishing of metals. Tin is broken into small pieces and melted over and over again, till it looks as bright as silver, and is then cooled, and ladled gradually into moulds, because, if quickly poured into them while hot, the tin becomes brittle. It is too soft and too valuable to be used alone, but is constantly employed for lining and coating iron utensils. It will bear beating into leaves only the thousandth part of an inch thick, and therefore, as tin-foil or tin-leaf, is much used for the lining of tea-caddies and the packing of articles that must be kept dry. Mixed with lead, tin forms pewter. It is also used with mercury for silvering the back of mirrors and looking-glasses, and, when dissolved in muriatic acid, it furnishes colours for dyers and calico-printers.

Edward now showed his father a piece of

ore labelled "needles of antimony," and asked if that were the same mineral used for antimonial wine. Mr. Goodman told him that oxide of antimony was used for that purpose. The metal itself is found nearly pure in veins amidst the mountains of Dauphiné and Sweden, as well as the Hartz Mountains. It is, as may be seen from that specimen, extremely brittle and easily corroded. It is very useful in the arts for the white metal often used instead of silver for music-plates. Its sulphuret forms the black powder with which the ladies of ancient times used to stain their eyebrows and eyelids. Oxide of antimony gives colour to the artificial imitations of beryls, topazes and yellow diamonds. Antimony and bismuth usually go together, but their power of conducting heat is so different that when two pieces are soldered together and a stream of galvanism is sent through them in one direction, a drop of water laid in the crease between them will boil; but when the current is reversed the drop of water will freeze.

Platina must be added to this list of metals. The term is a diminutive of "plata," the Spanish for silver. It is so scarce as to be almost as costly as gold, and is really nearly as valuable, as it is heavier and more difficult to melt, yet still more ductile and flexible. It is also very malleable,—that is, it can, when hot, be easily beaten out and welded to iron and steel. Neither air, water nor any simple acids injure it, though it can be converted into a chloride by nitro-muriatic acid. It is, therefore, exceedingly useful to the chemist for his crucibles, and is sometimes employed for the mirrors of reflecting telescopes. There are no platina-mines. It is generally found combined with palladium, rhodium, titanium, gold, iron and other metals, but in very small, heavy grains, seldom larger than a pea or a nut.

The last-named substances are some of the new metals which have been discovered during the past century, but not in sufficient quantities to make them very available for use. Cobalt, manganese, arsenic and nickel are the principal of these; though manganese was known in Pliny's time, being then deemed an earth. It is much used by potters and glass-makers for colouring, and yields brown to the calico-printer. The ore of manganese, called black wad, is remarkable for its spontaneous combustion with oil. It is used also for obtaining chlorine for bleaching-purposes.

Cobalt and its oxide, smalt, give a beautiful blue tint to glass, china-ware and paper. Nickel is susceptible of magnetism, and is therefore sometimes used for the mariner's compass.

Arsenic is employed for hardening candles, making flint-glass, and dyes of green, red, and yellow, as well as for tinting fireworks. It is much used in medicine, and yet is so deadly a poison that it destroys human and animal life very rapidly. Even its fumes are injurious to health.

Bismuth is a pretty-looking metal, not very common, and of little use, as it melts even before it is red-hot. This, however, adapts it for a soft, soldering material. Sir Isaac Newton composed a fusible metal consisting of eight parts of bismuth, five of tin and three of lead, which, though hard enough to polish when cold, would melt so readily in hot fluid that spoons made of it will disappear in stirring a cup of tea, to the no small dismay of an ignorant person.

These are not all the new metals. The following is a list of the whole; though of many of them little else is known than the name, suggested by the odour, colour, or some such circumstance; and they are not yet much used either in art or medicine.

1. Gold.
2. Silver.
3. Copper.
4. Iron.
5. Tin.
6. Lead.
7. Mercury, or Quicksilver.
8. Zinc.
9. Antimony,
10. Bismuth.
11. Cobalt.
12. Nickel.
13. Manganese.
14. Arsenic.
15. Platinum.
16. Palladium.
17. Rhodium.
18. Osmium,—so called from *osmé*, odour.
19. Iridium,—from its *iris* or rainbow hue.
20. Tungsten.
21. Tellurium,—from *tellus*, the earth.
22. Molybdenum,—from *molybdos*, lead.
23. Uranium.
24. Titanium.
25. Columbium.
26. Cerium.
27. Cadmium.
28. Chromium.
29. Vanadium.
30. Zirconium.
31. Sodium.
32. Potassium.
33. Calcium.
34. Silicon.
35. Aluminum.
36. Silenium.
37. Lithium.
38. Barium.
39. Strontium.
40. Magnesium.
41. Yttrium.
42. Glucinum.
43. Thorinium.*

The metals bracketed together are never

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* Some others have been named recently, but have scarcely been sufficiently *proved* to be classed with the above.

found separate in nature, and are of little use by themselves; but their oxides form the substances known as earths and alkalies, clay, sand, soda, potash, lime, magnesia, &c. At some other time these may be considered by themselves; but they come in here because they really have "a metallic basis," that is, their simplest and purest form is that of metals.

Edward asked his father if he thought it possible to change metals into gold, as the old alchemists fancied.

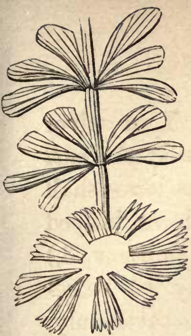
He replied that there is no evidence that it is possible. The history of the few imagined successes is so doubtful, and the circumstances described are so improbable, that we must think the alchemists were deceived, by the weight or colour, as to the value of the compounds they produced. Moreover, as the Scriptures say, "Thou canst not make one hair white or black," it is not likely that the greater change of lead to gold should be within human power.

In reply to this, Mr. Goodman remarked that it is very difficult to form a just opinion of their character or views. It is strange that they could have been willing to lend themselves to the impostures to which they certainly gave currency. Many of them were men of great learning and of irreproachable character. Roger Bacon (commonly called Friar Bacon, being an English monk of the order of the Franciscans, born in the year 1214,) exposed the absurdity of magic, necromancy and charms, yet professed his belief in alchemy.

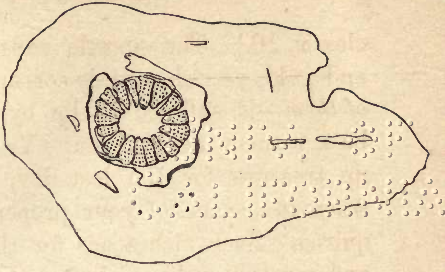
Doubtless many persons were deceived and deluded by plausible pretenders, and others were induced to embrace and propagate the belief from sordid and corrupt motives. If they had access to the sacred writings, they certainly did not take heed to them, or they would have learned to distrust the principles of their (so-called) science. They could not fail to notice how the lead, iron and silver, which the alchemists were most anxious to transmute into gold, are continually mentioned as "abiding the fire," as being only "tried," "purified," by its action, but always *retaining their own characteristics*. Indeed, these properties rendered metals a frequent type of God's dealings with his servants. "I will refine them as silver is refined, and try them as gold is tried," says God by his prophet Zechariah. (xiii. 9.) "When he hath tried me," says Job, (xxiii.

10,) "I shall come forth as gold." "He shall sit as a refiner and purifier of silver," (Mal. iii. 3;) an image which is peculiarly apt, as the silver is perfected only when the refiner can see his own image reflected in it, reminding us of the purpose of all affliction to assimilate our characters to that of the Lord Jesus Christ, the Great Refiner. (Ezek. xxii. 19, 22.) Then, again, iron and brass denote obstinacy on the part of man. "Thou art obstinate," says Isaiah, (xlviii. 4,) "thy neck is an iron sinew, and thy brow brass," and needed the threatened punishment, to be broken by a rod of iron. The Apostle Paul stigmatizes profession without practice as being but "as sounding brass." (1 Cor. xiii. 1.) God's enemies were said to sink "as *lead* in the mighty waters," (Exod. xv. 10,) or to be consumed in the fire, "cast away like refuse silver," (Jer. vi. 29, 30,) because the Lord had rejected them.

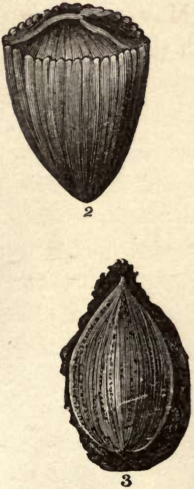
Mr. Goodman concluded his remarks on metals by urging his children to remember these illustrations of sin and of duty, and especially the warning given against covetousness; for the Bible says that "he that loveth silver shall not be satisfied with silver." (Eccles. v. 10.) The apostle adds, Your silver and gold, ye rich men, is corrupted; the *rust of them*—if suffered to lie by useless—shall be a witness against you. Ye have heaped up treasure for the last day, (James v. 3,) when an account of your property will be required. Such riches are for the earth only, and must be relinquished at the threshold of eternity. Those only who are rich in faith in our Saviour Jesus Christ will carry their wealth beyond the grave. May you, my children, be well furnished with the only true riches!



Sphenophyllum Schlotheimi;
nat. size.

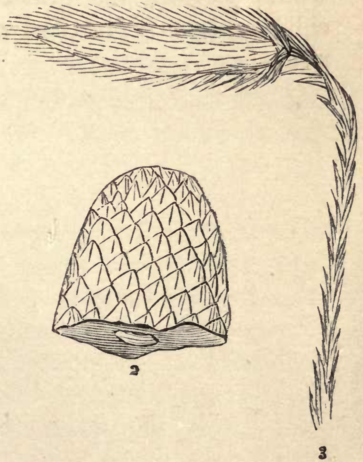


Transverse Section of Stigmaria ficoides; *nat.*
M. Adolphe Brongniart.
This specimen shows that the cylinder (*a* in *Lign.* 36) is formed of bundles of vascular tissue, disposed in rays.



Fossil Fruits, or Seed-Vessels; *nat.*
Fig. 2.—Carpolithes Bucklandii. *Coralline Oolite, Malton.*
3.—Trigonocarpum olivæforme. *Snibstone Colliery.*

☞ See page 91.



Lepidostrobi, the Fruit of Lepidodendra; *nat.*
Coalbrook Dale.
Fig. 2.—The upper part of a cone, displaying the imbricated surface.
3.—A young specimen attached to the extremity of a branch.

CHAPTER III.

COAL AND COMBUSTIBLES.

As summer advanced, the grotto became a favourite retreat with the whole family. Alice enjoyed counting up the names of the various contributions to its beauty as memorials of friendship, while Edward found in them ample food for his philosophical research, Mr. Goodman being the referee and instructor, whenever he could spare time for the purpose.

Among the treasures thus gathered were some remarkable pieces of coal and coke, which Edward had obtained from various colliers; some sulphurs his father had brought from abroad; bitumen from an Egyptian mummy; and one beautiful specimen of amber, enclosing an insect and part of a decayed leaf.

The young people were admiring these one morning, when Mr. Goodman joined them, and, pointing out the coal and bitumen, said that they might both be classed with amber in some respects.

"Indeed, father?" exclaimed Alice. "They seem very dissimilar."

Mr. Goodman replied that they are all combustibles, and have very similar origin; for it is now fully ascertained that they are the remains of ancient vegetation, coal being the moss, ferns and leaves, amber the gum, and bitumen the turpentine, sap and juices of whole forests, which, by the arrangements of God's wisdom, have been buried under ground, where they have gradually been changed into these useful minerals. Asphaltum, petroleum, naphtha, and some other compounds of hydrogen and carbon may be considered as varieties of coal,—though they are not always found together, for coal often occurs without bitumen or amber, but bitumen and amber are never found excepting in the neighbourhood of coal-formations.

Amber has been found from time immemorial on the sea-shore in Prussia, thrown up by the waves; but there are mines of it near Dantzic about one hundred feet deep, where there is a thick stratum of half-decomposed trees, yielding bitumen and amber, which sometimes hangs in stalactites from the branches. When burnt in the open air, it gives out a thick, pungent, fragrant smoke, leaving a light-shining black coke as its residue. When distilled, it yields succinic acid, so called from the Latin name of amber,—*succinum;* and the ash or residue is used for making fine black varnish.

Alice said she should never have supposed the pretty transparent amber could make coal,—it looked so very different.

Mr. Goodman remarked that the difference, after all, was great. It will bear a brilliant polish for beads and boxes. It may be boiled in water without softening or altering its appearance; but, when melted by heat, it yields oil, which is at first colourless, but, if exposed to light or to much greater heat, it becomes *brown,* and afterward a thick, *black* mass, almost like bitumen. It can be dissolved in sulphuric acid and some powerful oils, but, when once melted, cannot be restored to its natural transparency. It is of various colours, but most commonly either white or yellow, and is used very much for oil-varnishes. It was known to the ancient Arabs, Greeks and

Romans; indeed, the Arabs called it *ambra.* All these nations used it as a medicine, and the Romans valued it as a gem, importing it largely for ornamental purposes. It was supposed to have magical virtues, and was hung about the necks of children to preserve them from sickness,—a superstition which still continues in force in some countries. Thales, of Miletus, who lived six hundred years before Christ, noticed its electric property of attracting light bodies, when heated by rubbing; and the prophet Ezekiel, (i. 4; viii. 2,) who lived about the same time, mentions it as a substance familiar to the Jews in Chaldea. Most animals seem fond of amber, and eat it when they find it, without injurious effects.

Jet, also, is a sort of coal, but very hard and used for ornament: it is known as pitch-coal, and in Prussia it is called black amber. It takes its name from the river Gaya, in Asia Minor, where it was first noticed; it will bear a brilliant polish, and is cut into rosaries, boxes, brooches, inkstands, &c. The Isles of Skye and Feroe yield it, and large quantities are found in Mexico and other volcanic countries.

"What is bitumen, father?" asked Edward.

"Our specimen looks like a lump of very dry old resin."

Mr. Goodman, taking up the specimen, replied that bitumen is rather the general name for several sorts of mineral oil, pitch, mineral hatchetine, tallow and caoutchouc, which are found in the earth, seeming to have been originally vegetable juices, and are now in various stages of mineralization. The remains of ancient fish in some formations—such as the Old Red Sandstone—are converted into animal bitumen; and many rocks which give a fetid odour when broken are supposed to owe this property to animal bitumen from the decomposition of creatures now no longer existing.

Naphtha, petroleum and Barbadoes tar are highly inflammable mineral liquids, found issuing from the earth or dropping from the rocks in some parts of Europe and Asia. Naphtha is often collected into wells, and, when lighted, will burn for a long time. It is frequently used for lamps, and in Italy whole cities are lighted by it. Its odour is strong, but not unpleasant, and its power of dissolving oils and resins renders it very useful in the arts, especially in dissolving caoutchouc for water-proof clothing.

Petroleum is found in small quantities in England, but very abundantly in the East and West Indies. Near the town of Rainanghong, in the Birman Empire, there are no less than five hundred and twenty wells into which petroleum flows from adjacent coal-beds. No water ever penetrates into these wells; but more than four hundred thousand hogsheads of petroleum are annually procured, which is extensively used for lamps, and, when mixed with earth, furnishes an important supply of fuel. With us, in America, it is known as Seneca-oil, from the town of Seneca, in the State of New York, where it was first obtained. But it is abundant in many places in the coal-regions, especially around their edges, as on Oil Creek, in Northwestern Pennsylvania. At one time, a large quantity of it took fire on the surface of a small river in Ohio, and for half a mile the stream was one sheet of flame. It ascends with the salt water from the salt-borings, and is not only sold for burning-fluid and machine-oil, but is used for boiling the salt water, making salt, and even for lighting houses and villages with gas.

There are so many natural gas-vents in India, Persia, China and various parts of the world,—some of which have been burning for centuries,—that it is astonishing gas was not sooner turned to account in the arts. The salt-works of Thsee Lieon Teing, indeed, were long heated and lighted by these fiery fountains, which rose sometimes twenty or thirty feet high. Bamboo pipes carried the gas from the springs wherever needed, tubes of pipeclay being fixed at the burning points. At these works, a single gas-well heats more than three hundred kettles; and the fire thus kindled is said to be so exceedingly brisk that the cauldrons are useless in a few months. Three columns of flame carry off the superfluous gas. The village of Fredonia, in the State of New York, is lighted in a similar manner from natural gas. In both these cases the gas is ascertained to ascend from beds of bituminous coal.

Asphalte is so similar to petroleum as to be apparently the same thing in a more solid form. It occurs abundantly on the shores of the Dead Sea, which was anciently called *Lacus Asphaltites* in consequence. It was largely employed by the ancients in building. All writers agree that the bricks in the walls of Babylon were cemented with hot asphalte, which rendered them very solid. The Egyptians used it in embalming the dead. The lump of bitumen you have here was taken from the head of a mummy.

Much of the asphalte used in England is furnished by the Pitch Lake of Trinidad, which is three miles in circumference, of unknown thickness, and sometimes hard enough for men and cattle to walk upon it. Melted and mixed with sand, gravel or iron-slag, it forms a cheap and durable pavement; but very hot weather softens it so that it cannot very well be used for streets. There is a sort of black or brown limestone found near Bristol, and in Galway and Dalmatia, so full of bitumen that it is soft enough to be cut like soap. In Dalmatia this stone is used for building, and, when the walls are reared, fire is applied to them, and they burn white.

Coal-tar is a product of the distillation of gas-coal in the retorts of gas-houses. The residuum is coke, which is also produced in stacks and ovens for the purpose of being used in iron-furnaces, because the uncoked fat coal cakes and stops the draught. Coke weighs only one-half as much as the coal out of which it is made. It is a porous, lava-like, shining, ringing, brittle substance, somewhat resembling pumice-stone, but making an intense heat when burned.

Mineral tallow is scarcely soft enough to be made into candles, though it looks white and feels greasy. That and elastic bitumen, or mineral caoutchouc, are both varieties of bitumen,—greatly resembling the substances whose names they bear. There is also a material found in the iron-mines of Merthyr-Tydvil, in South Wales, of a soft, whitish or greenish hue, looking something like spermaceti, or bees'-wax, from which oil can be distilled at a low heat, leaving behind a coaly matter. It is wonderful that from so black a substance as cannel-coal and carbonaceous shale there is obtained, by simple distillation, a pure, white brilliant substance called paraffine, much used now for candles in the place of spermaceti, especially when hardened with a little arsenic.

Mellite, or honey-stone, so named from its colour and consistency, is another mineral, occurring at Thuringia, in Saxony, and in Switzerland, on bituminous wood and earthy coal, which has so many similar characteristics as to place it among combustible substances. In the blue clay of which Highgate Hill, in England, consists, small lumps of fossil gum copal are often found, and so like the copal gum of American trees now growing that it is called Highgate resin; and there can be no doubt, from its mode of burning, that it is of vegetable origin.

Edward here expressed wonder as to what different vegetables would come to, if they were left to themselves.

Mr. Goodman answered that the peat moss of Ireland would help to satisfy this curiosity, as it can be found in all stages between its early green growth and the black substance used for fuel. Peat is not known to occur in tropical regions, where vegetation decays too rapidly for its production. Bog-wood carries us another step on towards the coal-measures, its condition is so evidently a medium between vegetable wood and mineral coal.

"Uncle Joe," said Alice, "when he came back from Ireland, brought some bog-wood with him; but it was not hard enough for the wall of our grotto: so Edward put it into the table-drawer with the crumbling things." So saying, she produced two or three varieties.

But bog-wood, said her father, exhibits

various degrees of hardness as well as of blackness. Some specimens will bear carving into brooches and boxes, and are as black as coal; but all have the lightness of wood, and are liable to split in the same manner. It seems to have been produced by the slow burning action of the oxygen of the water in the bog where it is found,—a process well known to chemists, and called eremacausis. The Catholic inhabitants of Ireland make fragrant rosaries of bog-wood, and, when they are blessed by the Pope, they are highly prized by their superstitious owners, and are sent to all parts of the world as the most valuable presents.

Edward said that it would be interesting to find coal-mines where the coals did not seem yet completely formed.

Mr. Goodman said, laughingly, that they could hardly be called coal-mines till their contents were fully formed; but, in fact, the later coal-formations, called tertiary, exhibited the coal in the state of *lignite,* which is really a half-way condition between modern wood and the compacted coal of the secondary and primary formations. Moreover, ancient trees are seen in the rocks; and on the west coast of France, near Morlaix and Quimper, there are whole modern forests now standing under water, so that their condition can be easily examined and any changes watched. In a report* from these districts, dated 1856, on this very subject, the writer, Monsieur Durocher, stated that between Redon and Renai, places which can readily be found on the map, a marsh still exists, which is covered with water at high tides, but at low water the peasants procure large quantities of wood from it for their fires. At St. Nazaire, at the mouth of the river Loire, trunks of trees are still visible, in serried ranks; a remarkable fact, for the whole of that coast is now for the most part destitute of trees. M. Durocher considers that they were overwhelmed within a comparatively recent period by the encroachments of the sea. Documents exist proving that the destruction of the forests on the St. Malo coast took place between the eighth and twelfth centuries. That of Dol, near Mount St. Michael, is principally composed of oaks, which have become quite black and extremely hard. The neighbouring peasants have long used this wood for carving, as it is capable of receiving a very high polish. They call it "coeron," a word derived from the Celtic language. In Denmark there are deep wells, sunk through successive layers of rocks and submerged peat-bogs, with overthrown trunks of trees in such a state of preservation that they are quarried out and used for building and burning. What is most remarkable is the fact that each layer or bed of peat contains trunks of trees of a different kind, one having been an oak forest, another a beech, another a pine, and so on. Mr. Lesquereux, who studied all the bogs of Europe, has shown that the American coal-beds were made from such Great Dismal Swamps as now exist along the coasts of Virginia and the Carolinas. And Mr. Lyell and Mr. Dawson have described the ancient forests standing in the rocks of Nova Scotia, with their roots buried in the ancient coal-beds of that country. Similar forests are seen in all the coal-regions of the world.

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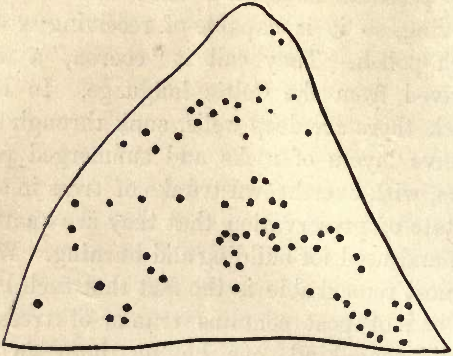
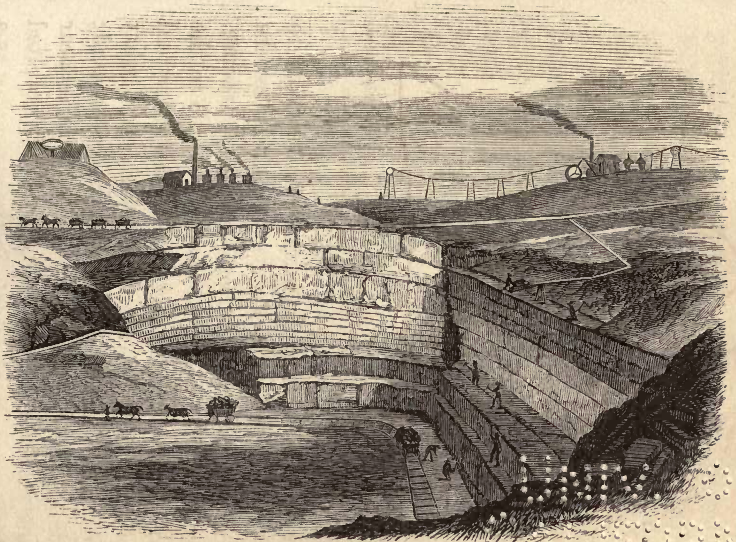
* See "Athenæum," Dec. 27, 1856.

In Parkfield Colliery, near Wolverhampton, there was a fossil forest so thickly studded that seventy-three stumps of trees were counted on a quarter of an acre. Here is a plan of the



Ground-plan of a fossil forest, Parkfield Colliery, near Wolverhampton, showing the position of 73 trees in a quarter of an acre.

spot. All the trees have been removed to different geological collections, and may be examined by the curious student of nature. This fossil forest was discovered where the loose rubbish is seen lying in the foreground of the following sketch,—which shows what is rarely to be met with now in England; that is, coal and ironstone beds lying so near the surface of the ground as to be excavated in the open light of day, in the same way as a railway-cutting; for in that country most of the beds lie so deep under ground that wells have to be sunk to reach them, sometimes



COAL AND IRONSTONE WORKS, PARKFIELD (ENGLAND).

Opp. p. 86.

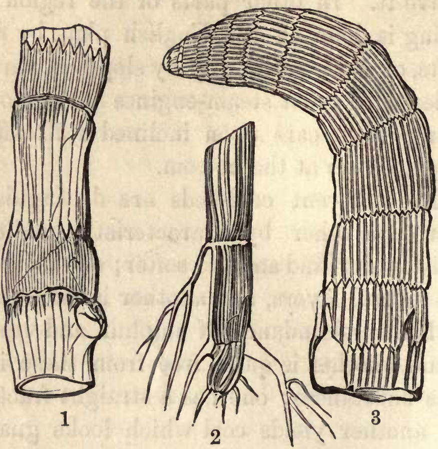
hundreds of yards in depth, at the mouths of which steam-engines, pumps for raising water, fans for blowing down air into the galleries, and machinery for hoisting the baskets or car-loads of coal to the surface, are placed at great expense. Sliding stages are also made to ascend and descend the sides of these well-shafts, on which the miners go up or down with speed and safety, instead of climbing dangerous, long, steep ladders, or being let up and down in baskets at the end of ropes, as in old times. Mining is much safer and cheaper now than it used to be.

The lowest bed of coal adjoining the little tram-road in the sketch above is eleven feet thick, and is known as the bottom-coal. Although here only about seven or eight yards below the surface, at another part of the colliery this bed is one hundred and fifty yards deep. Above the coal on the left-hand side, shown by the streaky lines, lies the white clay ironstone, in beds varying from two to six inches in thickness, and at this point eleven or twelve in number. The measures, lying all so regularly on the left-hand side of the sketch, are brought to a sudden termination by the slip or fault shown in the middle, the whole being thus thrown down twenty or thirty yards.

Such an open cut, but on a much grander scale, was one of the first coal-mines opened in America,—the Summit Mine, at Mauch Chunk, where various layers of coal lie horizontally so close together that the whole makes up a thickness of sixty feet. At first people thought that the whole mountain was a solid mass of coal; but by-and-by, after they had opened a vast quarry, in steps all round, like an ancient Roman amphitheatre, they came to the bottom, and then discovered that this group of coal-beds rolls over and down both sides of the mountain. Many hundred thousand tons a year are taken out of these mines, which present a grand appearance. In other parts of the anthracite-coal region the gangways are driven in at the edges of streams, and little railroads branch off into them from the main railroads coming up from the cities. Inside, there are rooms or breasts, rising with the coal from the level gangway to the outcrop at the summits or on the high hill-sides; and the coal, as it is mined, is allowed to slide down these breasts or shoots to where the cars stand ready in the gangway to receive it. In other parts of the region the mining is done on the English plan, by deep shafts, or more frequently by slopes at various angles, with great steam-engines at the mouth, letting down cars upon inclined railroads to the gangways at the bottom.

The different coal-beds are distinguished from each other by characteristic qualities: one is harder, and another softer; one is divided into several layers, and another is more solid; one has an abundance of sulphur and iron in it, and another is quite free from these injurious substances; one has a straight fracture, and another yields coal which looks gnarled and curly when broken to pieces; one will have many leaves and stems of certain kinds of plants, and another will show very few, or leaves and stems of quite another sort. In this way a bed is traced from one mining property to another.

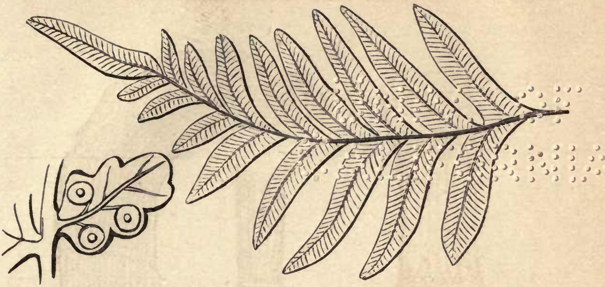
The vegetables which are found in ancient coal-beds are of various species, none of which now live upon this planet. Some are like the horse-tail plants of the present day. In the following cut (No. 1) is seen a stem with two sheaths and a bud.



Equisetum Lyellii. **Calamites Approximatus.**
Wealden. Ponceford. natural size.
Fig. 1.—A stem, having two sheaths, and a bud at the lowermost joint.
2.—Stem, with remains of roots.—½ *nat.*
3.—Calamites approximatus, showing the curved *lower* end of the plant.†—½ *nat.*

Others belong to the order of ferns, and are named commonly from the number of the nerves upon their leaves, or the shape of their teeth-like edges.

Others are the remains of gigantic trees, with extensive roots stretching out in all directions, covered with rootlets, which fill the "under clay" of every coal-bed. The bark of these tree-stems turned into coal or cast in



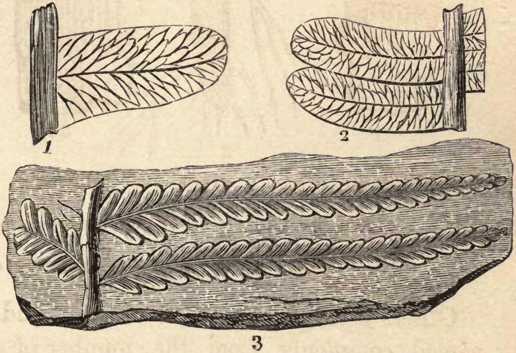
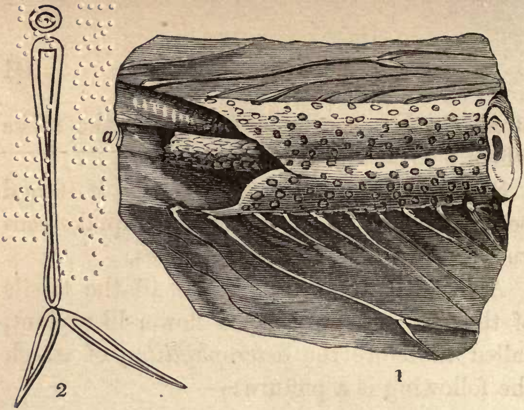


FIG. 1.—PECOPTERIS MURRAYANA; a pinnule with the fructification; *magnified. Inf. Oolite, Scarborough.*
2.—PECOPTERIS LONCHITICA. *Coal-shale, France.*

LONCHOPTERIS MANTELLI.
Wealden, Tilgate Forest.

FIG. 1 and 2.—Leaflets magnified, to show the reticulated venation.
3—A fragment of a frond; *nat.*

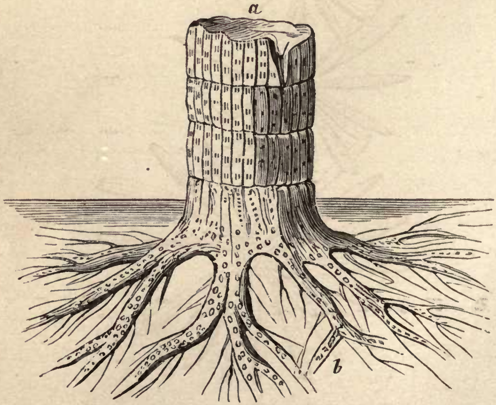
Opp. p. 90.



Stigmaria ficoides.—*Carboniferous. Derbyshire.*—¼ *nat.*

Fig. 1.—Portion of a stem, with some of the rootlets (formerly considered as leaves) extending into the surrounding clay. The internal axis is seen at *a*; and the corresponding groove on the portion of external surface that remains.

2.—An outline of one of the rootlets, with a tubercle to show the mode of its attachment by a ball and socket joint to the root.



Erect Stem of a Sigillaria, with Roots.

Coal Mine, near Liverpool.

a. The trunk of the tree, traversing a bed of Coal.

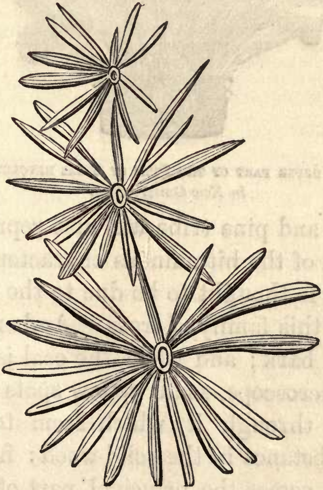
b. The roots (*Stigmariæ*) spreading out in the Under-clay.

Opp. p. 91.

stone moulds is commonly seen in the rocks which overlie the coal-beds.

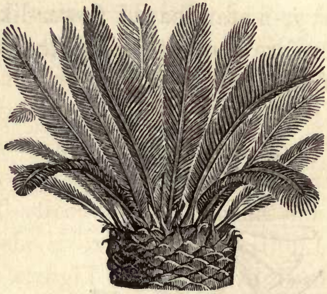
Sometimes the fruit is found, as if it had been shaken down by the earthquake-convulsions which buried up the trees.

Among the most common of all the fossils of the coal is a star-shaped flower-like plant, called therefore the *asterophyllites,* of which the following is a picture:—



Asterophyllites Equisetiformis: *nat. Coal-shale.* (*Foss Flor.*)

Palm-trees, or something like them, called Zamias and Cycades, with short stems and a plumy head of long and graceful leaves, grew in the ancient days of the secondary coal.



FOLIAGE AND UPPER PART OF THE STEM OF CYCAS REVOLUTA. $\frac{1}{12}$ *nat.*
In Kew Conservatory.

The fir and pine tribe was also represented, and much of the bituminous character of some coal-beds is thought to be due to the resinous nature of this family of trees. Amber exuded from the bark; and when the coal is studied with a microscope, small yellow spots are seen scattered through it, which seem to be the amber substance in the solid wood: from this, no doubt, comes the principal part of the gas we get from coal.

It seems generally agreed by the learned that the first mention of coal, as we understand that name, occurs about two thousand years ago, in the writings of Theophrastus, a pupil of Aristotle. He devoted the long period of one hundred and six years to scientific inquiry, and died lamenting that the shortness of life prevented any great attainments. About twenty of his works have been preserved; and in his book on stones he remarks, "Those fossil substances called coals, and broken for use, are earthy. They kindle, however, and burn like wood-coal. They are found in Liguria, where there is also amber and ore used by smiths." Liguria was the ancient name for that part of Italy of which Leghorn and Genoa are now the principal towns.

Coal seems to have been known to the Chinese before it was known in Europe; for the earliest traveller to that country whose journal we possess reported that that ingenious people "burnt a black stone which was as good fuel as wood." Their borings are done with a rope, and their mines are some of them deep.

The Bible mentions coals of fire earlier than Theophrastus, for they are spoken of by the prophets, and even in the time of Moses; but at that period the word was used to signify any sort of fuel. The Saxon word *col*, the German *kohl* and the Danish *kul* are all names in those languages for mineral *coal*, which seems to have been an old British word, now represented in Irish by the word *guel*, and in the Cornish dialect by *kolon* to this day. Indeed, some antiquaries zealously contend that a flint axe found stuck in a vein of coal in Monmouthshire proves that the early natives of England were acquainted with this useful substance. But one would think that, if the early Britons had been acquainted with mineral coal, it would have continued in use: therefore, the fact that it has not, must be considered a serious objection to the supposition. Charters still exist, showing that coal was known and used in England during the ninth and tenth centuries,—although the Newcastle pits were not taken under royal protection till 1239. In 1245, we find a regular system of collieries and coal-vessels arranged for the conveyance of "sea-coal," as it was long called, because it was taken by sea along the coasts to London and other ports. But at that period it was not plentiful in London; for in 1306 King Edward I. forbade, by proclamation, the burning of coal in the city, on account of its sulphurous smoke and smell. As wood became scarce in England from neglect of planting new forests, mineral coal gradually came into use; yet, as late as 1600, Stowe relates that "the nice dames of London would not come into any house or room where sea-coals were burned, nor willingly eat of the meat that was either sod or roasted with sea-coal fires." It has not been long ago that many of the French had so great a prejudice against the use of coals that landlords ejected tenants for using them, and drawing-rooms were almost emptied of guests when warmed with a coal-fire. In America, where we burn anthracite coal chiefly, all this sounds strange enough; but a visit to Pittsburg, where the bituminous coal is altogether used, will readily explain it. By-and-by coals found their way into the palace of royalty; and so large a tax was raised from coals imported into London that it aided considerably in the rebuilding St. Paul's Cathedral and the fifty-two parish churches destroyed by the great fire of 1666. The British coal-trade has now reached thirty millions of tons.

Coals with seventy different names are in the English markets,—names derived from the localities whence they are procured, as Wallsend, Newcastle, Welsh, &c.; but many of these are so much alike that the coal-merchants themselves find it difficult to state a difference between them. The American market is quite as full of names, such as Diamond, Peach Orchard, Buck Mountain, Lykin's Valley, Lehigh, Cumberland, Broad-top, Alleghany, Westmoreland, Blossburg, &c. &c. Many of these are the names of coal-regions or single basins; and many others are the names of single mines or beds of coal. The geologist recognises only three great kinds,—bituminous, semi-bituminous and anthracite. The English geologist has subdivided these into fourteen sorts of coal, according as some yield white and others red or black ashes; some burn quickly, and others slowly; some produce much smoke, and others little; some cake together as they burn, and others crumble into fine pieces. All have distinct values for these different qualities, according to the kind of use to be made of them.

The principal varieties of bituminous coal are the caking, cubic, splint and cannel coals,—all very bituminous, yielding smoke and gas.

Anthracite, or "blind coal," is not bituminous, and does not smoke or soil the fingers. It is a natural coke, found in South Wales, in Belgium and in Eastern Pennsylvania so plentifully that whole cities use it and are entirely free from smoke,—which is a great advantage; for in London, Liverpool, Pittsburg and other cities which use bituminous or smoking coals, the new buildings soon become dark and dingy with soot. The anthracite coal-beds were originally, however, as bituminous as the rest, and in fact can be traced along so as to be proved to be the very same deposits. How the bitumen or oily and gaseous parts have been separated and driven off, so as to leave hard, crystalline anthracite, it would be hard to tell. The effect has been produced in Wales by the intrusion of trap dikes or ancient lava currents; but nothing of that kind is visible in the anthracite regions of America. It is possible that warm gases or steam from below have penetrated the cracked crust of the earth and turned the bituminous coal-beds into anthracite; and this is the more probable, seeing that the bituminous coal-beds lie very flat and undisturbed, whereas the anthracite coal-beds are tossed and crumpled, and even sometimes turned quite over on their backs, forming long, pointed, narrow troughs or basins, with wrinkled sides; while the rocks which enclose the coal-beds are baked as if by heat and broken into millions of fragments by the movements to which they have been subjected: so that it would have been an easy thing for hot vapours from below to find their way to the surface through innumerable cracks. It is a curious fact that at the eastern end of all the anthracite basins the coal is hardest and heaviest of all; while at the western ends of the same basins it contains from ten to fourteen per cent. of volatile matter. Going still farther west, to Broad Top, Cumberland and the Alleghany Mountains, we find the semi-bituminous coal-beds containing from fifteen to twenty per cent.; while the Ohio River coals contain from thirty-five to fifty per cent. In Arkansas, the anthracite coal appears again; but in California and Central America all the coal yet discovered belongs to the tertiary formation, and is very soft and smoky and full of ashes. Such, also, is the coal of Texas and of the head-waters of the Missouri and Judith Rivers. The age of the Richmond, Dan River and Deep River coal-basins, in Eastern Virginia and North Carolina, is midway between the old coal-measures of Pennsylvania and the West and these modern tertiary coal-measures of the Pacific coast.

In Germany there is a kind of soft, earthy "brown coal" much in use, which is made into bricks and fed into great china-ware stoves with hinged tin gloves. It is a dirty, crumbly fuel, but the best the poor people can get. In Wales there is a variety called by the cottagers stone-coal. It is found generally in very small pieces, which are mixed with clay into "coal balls." They are difficult to light at first, but, when once ignited, will burn so long, and so slowly, that the fire is not extinguished for years. The good housewives vie with each other in the taste with which these balls are piled into the grate, at the top of the fire, to supply the destruction below. It is considered quite a calamity if the fire goes out. There was a company once formed in New York to mix the broken and fine refuse coal of Pottsville and Mauch Chunk with clay, to make into similar bricks or balls for the Philadelphia market; but it was found to be too costly at the present price of coal. Hills of this refuse coal are annually washed down the rivers by the rains into the sea. At some future day so great a waste will be prevented. The coal comes out of the mine in great lumps, and is crushed between iron rollers set with teeth, and shot down long inclined planes into the cars, which take it to the cities. In England, great cranes let down the cars, full of soft coal which will not bear much handling, into the holds of vessels lying far below.

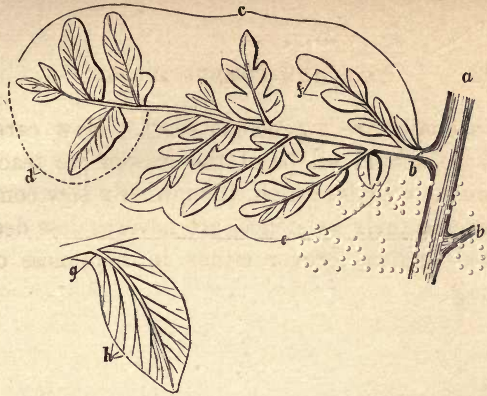
That coal has been so long made ready in the earth for men to use it, we may regard as an eminent and admirable result of the Creator's wise use of the past and seemingly useless exuberance of vegetable nature; for thus the decay of the earth's ancient beauty is made subservient to the comfort and prosperity of the future generations of its inhabitants. Moreover, nothing is more remarkable than this "gathering up of fragments, that nothing be lost," to be observed in all God's works; and so strikingly is this perceived in every deeper discovery of scientific truth that men of science are prepared to assert that no new matter has been added to our world, but that the whole record of natural history is simply the history of changes, wonderful and varied, and perhaps still inexhaustible.

"Well, now," said Edward, "when I look at the spring buds and blossoms, I like to think they are all God's new work just finished: as David says, 'Thou renewest the face of the earth.'"

"You may enjoy that pleasure still, my boy," said his father; "for are not the skill and benevolence of our heavenly Father more wonderful still, when new and beautiful fruits and flowers are created from the old soil and gases, so disagreeable to our senses?"

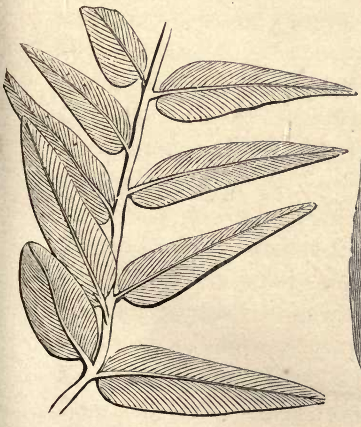
"Oh, yes; but I should like to find out something really fresh created,—actually lately formed by God."

"We must leave the world of matter, then, my dear Edward, and use the eyes of our minds; and then we may discern that every infant possesses a newly-created spirit,—one sent into this world to be educated and trained for immortality through the redemption by Jesus Christ. Thus, infancy and childhood in a family are a precious trust. How careful we should all be of the lessons we teach their new souls, which, though only now commencing their existence, are nevertheless destined to live forever either in happiness or woe!"

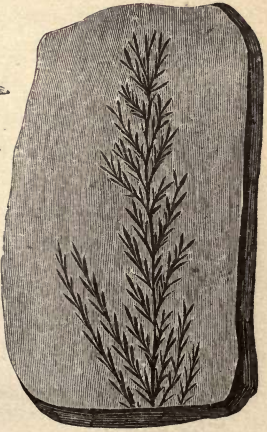


Pecopteris Sillimani; *nat.* *Coal Shale, Ohio.*

a. The Stem.
b. Leaf-stalk, or petiole.
c. Leaf, or frond, which is bipinnate.
d. *e*. Leaflets, or pinnæ; the upper, *d*, are entire; the lower, *e*, are pinnatifid.
f. The pinnules, lobes, or segments.
g. The midrib, or median vein.
h. The veins. The veins are introduced in the leaflets, *d*; but in the lower ones, *e*, the midribs only are marked.



Neuropteris acuminata; *nat.*
In Coal-shale, Yorkshire.
☞ See page 90.



Sphenopteris Mantelli; *nat.*
Wealden, Tilgate Forest.

Opp. p. 102.

CHAPTER IV.

CLAY AND SLATE.

It was summer-time, and the weather so unusually hot that Edward and Alice spent most of their leisure hours in their favourite grotto,—more attractive than ever now, from the knowledge they were acquiring of the materials of which it was constructed. Like most active young people, they were continually devising and attempting new improvements; and the sultry weather suggested the delights of a cooling fountain, which, after some surveying and planning, Edward undertook to contrive.

There was a mill-dam not far off: so a few yards of gutta-percha tubing sufficed to bring water to his basin, or, as he chose to call it, his reservoir, which he dug with mathematical precision in the centre of a small grass-plat, and lined neatly with clay, ornamented also with little pebbles stuck in regular patterns. The tubing was brought up amidst some rock-work in the middle, and furnished with a tap. Soon, therefore, a small jet of brilliant drops sparkled in the sunshine, adding their pleasant melody to the sweet song of birds, which, to Alice's great admiration, speedily learned to slake their thirst in the tiny pond. The young engineer beheld it with triumph; and, an artist having lately modelled a bust of his grandfather, Edward was seized with an ambition to try that art and decorate his fountain with figures and statues. He tempered his clay, and kneaded and modelled, first, a head of Minerva, the fabulous goddess of wisdom, which, however, looked unmeaning without any body; and that failed. Smaller figures were more successful; but the rain spoiled them. Alice suggested baking, after the fashion of potters; and forthwith his mother found her oven full of grotesque-looking objects, which puzzled her not a little, till Edward explained which was a lion and which was a man. After all, however, they were deemed unworthy of a place in the grotto; and Mrs. Goodman made them a present of a few objects in biscuit-ware, which, after their numerous disappointments, were thankfully accepted.

The scheme had not been without benefit, however; for it had discovered to the young people the very various appearances and qualities of the clay they had worked with.

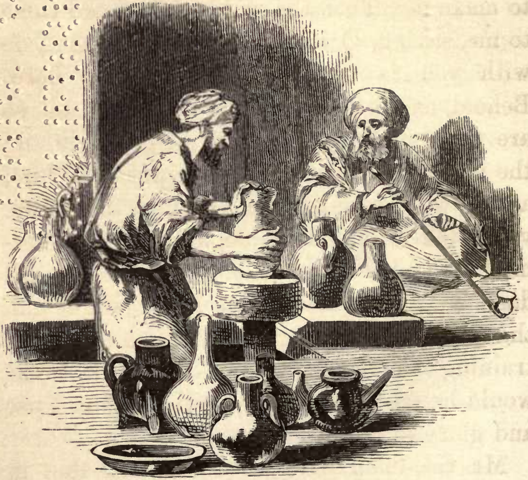
"How pretty this biscuit-ware is, father!" said Edward, when exhibiting his improvements to Mr. Goodman. "I wish I could find some of the clay it is made of."

Mr. Goodman replied that such a material as that is never found: it undergoes a vast deal of purification, or is mixed with other substances to give it its delicacy. CLAY is a mineral substance, opaque and dull-looking, never crystallizing,—often soft enough to be cut or scratched by iron, though sometimes so hard as to bear powdering. When breathed on, most clay yields a peculiar smell, termed argillaceous, from the Latin word *argilla*, (clay;) but this smell generally arises from some admixture of oxide of iron, for perfectly pure clays have no odour.

Clay is spread over our country so plentifully that some is found almost everywhere; and it is of red, yellow, blue or white colour, according to the substances mixed with it. All clays become plastic, or easily moulded, and tenacious, by mixing with water. The purer varieties may be known by their sticking to the tongue and feeling unctuous, or greasy, to the finger. This plastic and unctuous property is due to the proportion of alumina mingling with the clay: indeed, this alumina used to be called *argil,* as being obtained chiefly from the argillaceous or clayey earths; but it is now procured in larger proportions from alum. Clays become so hardened by baking that they will strike fire with flint, and will bear an amazing degree of heat without crumbling: hence fire-bricks are so serviceable. The fire-clay of Stourbridge and Windsor yields large square slabs for sugar-boilers, drying-kilns, brewers' coppers, &c. The white clay-beds beneath coal-beds furnish much of the best fire-brick used in constructing blast-furnaces and the puddling-furnaces of rolling-mills. The fire-clay bricks of New York and Philadelphia come from extensive beds of clay beneath Amboy. But the common building-bricks of the cities of the seaboard are made from coarser clays dug in their neighbourhood. Almost all the great cities of the world are built on clay and gravel beds of a late age. The colour varies in different cities according to the amount of iron which happens to be in the clay. The bricks of Philadelphia are a soft deep red; those of New York and Boston are of a paler, yellowish tint, and are commonly painted,—which is never done in Philadelphia until a house is very old. In old times the bricks which were nearest the fire in the kiln, and thus burned black, were used as ornamental in the walls. Some of these old houses and graveyard-walls still exist, and present a peculiar appearance.

All these clay-beds are at or near the surface of the earth. But there were very ancient clay-beds which have been turned into hard rock, called clay-slate; and when these are crystallized crosswise and split into planes they form slate-quarries, which furnish the slates for roofs and for writing-tables. The slate-quarries of Tremadoc, in North Wales, are wonderful excavations made in the tops of mountains, and the slates are let down by long inclined planes and railroads to the sea. In Pennsylvania the quarries of Slatington, on the Lehigh, and others on the Delaware and Hudson, are becoming equally celebrated. Similar slate-quarries occur in other parts of the globe, as in France and Germany. Where there are no slates, shingles of cedar or cypress are used for roofs; but when timber is scarce, then the poor people must use straw to thatch their dwellings.

It is an interesting fact that the most useful minerals are generally situated so as to be easily obtained by the industry of man. Clay is universally spread over the earth, and we find it used in all countries, and from the most remote ages, for very various purposes, from the "bricks thoroughly burned," of which the tower of Babel was constructed, (Gen. xi. 3,) to the glazed earthenware coffins found in South Babylonia, specimens of which are now in the British Museum. Cups, plates, inscribed cylinders, tablets, water-jars, bottles, dishes, and many other domestic utensils, were early made of clay; and so common was its use, that it is perpetually employed as a metaphor in the Scriptures. Were the Israelites rebellious against God, the prophet was instructed to threaten that their princes should be trodden down as the potter treadeth clay. (Isa. xli. 25.) "Go down to the potter's house," said Jehovah to his servant Jeremiah, "and there will I cause thee to hear my words." (Jer. xviii. 1–6.) And very striking must have been the message, for, lo! "he



EASTERN POTTER.

Opp. p. 109.

wrought a work on the wheels. And the vessel that he made of clay was marred in the hand of the potter: so he made it again another vessel, as seemed good to the potter to make it. Then the word of the Lord came to me, saying, O house of Israel, cannot I do with you as this potter? saith the Lord. Behold, as the clay is in the potter's hand, so are ye in mine hand." Little, probably, did the potter dream of the honour put upon him, as he wondered at the prophet's unwonted visit; but if he understood, as doubtless Jeremiah explained the matter, how must his daily occupation have henceforth taught him the importance of right preparation and right training for the service of the Lord, if he would become a vessel fit for the Master's use and glory in eternity!

Mr. Goodman went on to remark that in England clay is seen being made into bricks in almost every locality, with very simple establishments, sometimes with scarcely even a shed; and whole families are engaged, women and children assisting to make the most of their little patch of clay ground.

The same clay does not make both bricks and pottery, for brick clay is often coarse and mixed with stone and fragments of rock, while the plastic or potter's clay must always be a finer material. It often contains, however, the remains of shells, the teeth of fish, and woody fibres, but all so decomposed, or rotted down, as to be almost indistinguishable. All the potter's clays can, when dry, be polished by the finger. Ingenious lads often amuse themselves by making seals and stamps of this clay and engraving and polishing them easily; and they will gradually become very hard by exposure to the sun and air. When made into a paste, some of these potter's clays are slightly transparent; but they become very hard, and cannot be melted in a furnace. Some of them become white, others red, in great heat: so that they are singularly well adapted for cooking-utensils, as well as for cups and saucers, and other domestic articles.

The finest china-ware is made from porcelain earth, or kaolin, as the Chinese call it, which results from the decomposed felspar of granite, and varies in colour from the purest white to yellow or red. The kaolin of Cornwall is so white and so plentiful that for miles the ground looks as if covered with snow; but the Chinese and Japanese kaolins are generally whiter, and more unctuous to the touch, than those of Europe. In Brandon, Vermont, there is a very remarkable quarry of kaolin, a hundred feet deep, alongside of a quarry of lignite or tertiary coal full of leaves of trees and three-sided fruits, none of which are now known to grow upon the earth. Professor Hitchcock, of Amherst College, has described more than twenty varieties of these fruits. This coal is used to burn the kaolin and smelt the iron-ore which is also found in this singular deposit. The State of Delaware also furnishes large quantities of kaolin; and the manufacture of fine china once succeeded very well in Philadelphia, but was given up at last, owing to the competition of the foreign article. In Europe the finest china is now made. The royal manufactory at Sèvres, near Paris, produces ware of extraordinary beauty and costliness. But China has been the country of clay-bakers for thousands of years; and the porcelain dishes, vases and towers of china are some of them a thousand years old and preserved with religious care. It is all made of kaolin or the finer kinds of clay.

This kaolin furnishes our tea-services; but it undergoes considerable preparation, by boiling, washing, stirring, skimming and settling, and has generally some addition of ground flint, and such things as experience suggests for beauty or for strength. Biscuit-ware ornaments are made of this material, with ivory-white or ground bones to render it opaque. Brooches, buttons, mosaic pavement and some artificial gems are made of this clay. Pipe-clay is very similar to kaolin. The best is quite white, and is found near Poole and Purbeck, in Dorsetshire; but some is gray, some black, and some violet colour. Some of the white clays become gray in a low heat, and white again when subjected to a stronger heat.

It has rather puzzled observers to discover the cause of this very curious effect; and many reasons have been suggested. The most plausible theory is that the natural softness of these clays was owing to mineral oil, which burned, in low temperature, to coal, and thus tinged them black, while the higher degrees of heat caused it to fly off in vapour, and left the clay white; for much of the decomposed animal and vegetable carbon of all ages remains in all clays. This pipe-clay is not only used, as its name implies, for tobacco-pipes, but also for the cleaning of white leather used in soldiers' accoutrements and for the fulling or scouring of woollen cloths. Indeed, any fine clay that does not stain may be used for this purpose. Its cleansing property consists in its quickly absorbing all the oil or grease which it touches, while it also thickens the cloth by causing the little hairs or fibres to curl up.

Fuller's earth is found in Surrey, Hampshire and Bedfordshire, (England,) and is of a greenish-brown colour. It was formerly deemed so important to the woollen trade that its exportation was prohibited; but now soap has rather superseded it. In Sweden the clay we term "fuller's earth" is called stone-marrow, from its appearance; and in Crim Tartary it is used instead of soap for washing. Mothers often use it in the nursery; for it is very cleansing, and when there is any unhealthy secretion, such as often arises in the folds of infant children's skin, it is useful in absorbing this heating moisture and thus giving the skin time to recover its proper functions.

This mode of cleansing cloth is called fulling, from the Latin word *fullo*, a fuller of cloth;

and this property of clay was known in such very early times that "the fuller's field" is mentioned as a conspicuous spot in the reign of Hezekiah, and "fuller's soap" is used by Malachi as an illustration to explain the purifying influences of the Redeemer's lessons. Mal. iii. 2.

Loam is an impure kind of potter's clay, mixed with mica and iron-ochre, and is often used to correct the dryness of land. Corn grows best on clayey lands: so that the farmer often spreads loam as a manure. There is a green sand in New Jersey, Delaware, Maryland and Virginia, which lies upon clay, and is a remarkable manure for the barren, sandy lands along the Atlantic coasts, making the pine-forest soil as fertile as a garden. But, when spread upon the soil of the hills back of Trenton, Philadelphia and Baltimore, it is of no value whatever, because its fertilizing quality depends upon the green potash that is in it, and these hill-soils come from rocks which have already more potash in them than they want. They want, therefore, not green-sand marl, but shell marl, or lime, or plaster of Paris, or phosphate manures. All this the farmer learns who studies agricultural chemistry.

All clay is soft in its earliest natural condition, but it becomes hard in time, even without burning; for the ancient cities of Babylon seem to have been built entirely of sun-dried bricks, which are remarkably hard and compact; but the slate of which I spoke as forming mountains shows how hard clay may become by the aid of time and pressure, moisture, heat and the forces of crystallization. We find it in all stages of firmness, from the slate-clay, which is found in flat tabular fragments easily breaking down in water, to the clay-slate of the Pentland Hills and the adhesive slate of Montmartre near Paris, occurring between blocks of impure gypsum, in large straight plates, like sheets of pasteboard. It absorbs water rapidly, with air-bubbles and a crackling sound. So firm and smooth are the large slabs in which slate occurs in North Wales, that a single slab will sometimes suffice for a road-bridge over a mountain-stream, and they are commonly used as fences. Many country stiles between fields are made of slates in Devonshire. They lie so evenly, too, in the quarries there, that it is easy to pull one out for writing,—though, of course, they are improved by grinding and polishing the surface in some degree.

The slate of these old rocks varies in colour from nearly white to gray, green, black, and sometimes striped. Silica, or flint, sometimes mingles with the clay, forming slate, and renders it more or less brittle. The coloured slates are used for the roofing of houses, the flooring of dairies and conservatories, and, when tastefully disposed in patterns, look pretty and cheerful. Though clay so readily imbibes water, good slate is quite impervious to moisture, which renders it so fit for domestic purposes, and in architecture for preventing the ascent of moisture from the foundation up the wall of a building. A layer of slates is, therefore, laid between the stones of the foundation and the first courses of wall-brick. The blackest and finest-grained specimens are made into school-slates. Tombstones, fancy tables, vases, flower-pots and many other articles are made of the prettier varieties. The older slate-rocks appear to have been subjected to many convulsions of nature, as the strata are much broken and heaved up; and the fine mountain scenery of the White Mountains and Blue Ridge, of the range of Snowden, in Wales, and of the Alps of Switzerland, is due to this. Most of the high peaks which ascend above the fields of eternal snow are *aiguilles*, or needles, of clay-slate rock. Near the slate-quarries of Wales it seems a complete world of slate, and the village churches and churchyards look as if they were all in mourning, from the black slate walls and tombstones so prevalent there. Some of the latter are prettily carved, and relieved by inscriptions in gilt letters.

The hone-stone of Turkey, used for sharpening knives, and the whetstone of Germany, for gardeners' scythes, are both compact sorts of clay-slate. It is either of a greenish gray or pale drab colour. Though so smooth and hard, it is easily cut with the knife or graving-tool, and is therefore used by artists for delicate sculpture. So finely and elaborately may it be carved, that a piece of German hone-stone only the size of a small octavo volume, having the scene of naming John the Baptist exquisitely depicted on it by the celebrated Albert Durer, has been valued at two thousand five hundred dollars. Clay can thus be made to rise in value by genius and patient labour. This same sculpture required six months' close application, and was then deemed to have been quickly accomplished.

Clay forms the cement of many conglomerate or mixed rocks, such as toadstone and gray-wacke, which is variegated with fragments of quartz, flinty slate, felspar, mica and clay-slate. These fragments vary in size from that of a hen's egg to little grains. Clay-stone is hard and purple, like petrified clay. Indeed, clay mingles so much with sand and limestone rocks that it is often impossible to determine where they pass into one another. Geologists call them argillaceous sandstones, or sandy clay-rock, and argillaceous limestones, or calcareous clay-rock. All the rocks of the world are made up partly of clay, partly of sand and partly of iron, potash, soda, magnesia, or other materials; but clay is the next most abundant after sand. Sometimes near volcanoes, or in countries where volcanoes once existed which are now extinct, the clay-rocks have hardened and burned by nature into various and beautiful minerals.

Some varieties of porphyry seem to have been thus produced. The name porphyry signifies purple, from the Greek word *porphura*, as that was the usual colour of this stone used by the ancients. In the walls of our grotto there is a beautiful specimen of Egyptian porphyry, as well as other varieties. It may be observed how compact and close-grained it is, of a bright-reddish purple, with white marks. It certainly does look something like baked clay, but it does not smell much when wetted; for when clay has been once heated it loses the plastic quality and clayey smell, which cannot be restored unless acid is added to it.

Porphyry is a compound rock, with large crystals of felspar (sand-clay and potash or soda) so firmly imbedded in cement as to become the hardest of all rocks, and, when polished, perhaps the most enduring. Though it derives its name from the purple variety, it exhibits almost every colour,—green, deep red, black, dark brown, gray and flesh colour. Quartz, felspar, mica and fragments of other porphyries form brilliant spots, often finely contrasted, both in colour and substance, with the material in which they are imbedded.

The spots in some porphyries are very small, as in one of the specimens; in others they run into large blotches of an inch broad; occasionally they exhibit veins, and are greatly valued for architectural purposes,—especially the more crystalline sorts. There is abundance in the island of Minorca, far superior to all the best Italian marbles; and the immense strata of Egypt and Arabia Petræa are still inexhaustible. In Germany, England and Ireland, it occurs in detached nodules; and near Blair Athol, in Scotland, there is a fine example of a bed of porphyry slate in rocks of mica.

Porphyry is not often used now, as it is very difficult to cut, from its extreme hardness. In Egypt there were three fine columns of black porphyry, called Cleopatra's Needles; and several similar ones are seen at Rome in some of the most ancient buildings. One of these is in the tomb of Constantia, the Emperor Constantine's daughter. In the Tuilleries, at Paris, there were busts of Apollo and twelve emperors, all in porphyry; and at Aix-la-Chapelle are twelve exquisite columns, brought from Italy by Charlemagne. In the middle ages the art of cutting porphyry seems to have been lost, as Addison, who was curious in such matters, visited Rome in 1700, and relates that even then he could only find one workman attempting to carve it, and the process was so slow and the success so indifferent that he could scarcely gain a livelihood. Many persons have tried to revive the art, and devised methods of softening the stone, or grinding it with an untoothed iron saw and powdered freestone; and lately the Duke of Wellington's sarcophagus has been cut out of a boulder of porphyry which had lain for ages upon the Treffray estate at Luxalyan, in Cornwall. It is of a rich, reddish-brown colour, with yellow markings. Heraldic arms have been carved on a boss at each end.

At first thought, it seems strange that any art once known should be ever lost. But perhaps we need not wonder at it much, for history details so many wars desolating the earth that the arts of peace must sometimes have been forgotten. Moreover, the possessors of knowledge were often too anxious to render themselves important by treasuring it as a secret, instead of regarding it as a talent intrusted to them for the general good.

Many of the crayons used in drawing are really slate or hardened clayey earth: the black, gray and red chalks are mostly of these materials, which are sometimes boiled in oil to render them compact enough for use.

The stiff blue clay, lying to so great a depth almost everywhere round and beneath London, is a marine deposit, containing numberless remains of extraordinary sea-animals, none of which now exist. A similar sort of clay is observed at the foot of the Himalaya Mountains of India. This blue clay forms the reservoir whence the deep wells of London are supplied with fine soft water.

"Ah, I suppose the clay holds the water," said Edward; "for it all sank in my pond till I plastered it with clay."

"Just so," answered Mr. Goodman: "therefore you can easily understand the important use of these beds of clay in the formation of our earth, for collecting and retaining that necessary of animal and vegetable life, water; and when these natural reservoirs overflow, streams trickle through the soil, and, joining others, form rivers, lakes and seas. When the basin structure of the rocks is extensive and the waters run down the slopes under ground for many miles, they rise in Artesian wells to the surface with great force. The Du Pont well at Louisville, in Kentucky, is two thousand one hundred and eighty feet deep; and the water, which comes seventy-five miles in a straight line from hills five hundred feet above the level of the city, rises from the mouth of the well in a jet one hundred feet in the air, with a force to carry up small stones. Limestone-clay rocks form the bottom of this layer of water. The well at St. Louis, in Missouri, is two hundred feet deeper, and was intended to furnish pure water for the sugar-refinery of Mr. Belcher, who had it dug; but the water turned out to be salt, and worthless for that purpose."

Mr. Goodman went on to say that clay is useful also as a purifying agent in manufacturing sugar, chiefly by preventing its cooling too quickly; and gardeners also use it in grafting trees.

Alumina, or pure clay, is so closely allied to common clay that we ought not to omit its mention now. These pretty crystals of alum are only one form of alumina, produced, by a long and troublesome process of melting, boiling and washing, from a primitive clayey-looking earth found in Sweden, England, Saxony and Italy. Alumina is seldom found native, although it is so widely diffused in nature as to mingle in almost every soil and rock. It is this ingredient that gives clay its plastic or moulding quality; and yet when added to tallow it hardens it. Sir Humphry Davy demonstrated alumina to be an oxide of the metal aluminum. In pure oxygen gas this metal burns with so dazzling a light that the eye can scarcely bear it, and the heat is intense.

The crystallized salts of alumina, known as alum, are largely used, not only in hardening tallow, but in dyeing calico and tanning leather, and making porcelain, bricks, pottery and crucibles. It is used also in preparing the artists' paint, called lake; and aluminous earth, finely powdered and tinged, constitutes many of our coloured crayons. Printers' cushions, and the blocks used by calico-printers, are often rubbed with burned alum to remove any greasiness which would prevent the ink and dye from sticking to the surface. Wood well soaked in a solution of alum does not easily burn; paper steeped in it resists both fire and water, fitting it for holding gunpowder. Alum mixed in milk helps the separation of the butter; while a very small quantity will clear turbid water. It is also used in making pyrophorus, or air-tinder,—a material which takes fire merely on exposure to the air. At the English alum-works it is crystallized in the shape of small barrels, the inner portions of which exhibit beautiful crystals; but a better sort comes from Rome, in small cubes. The Chinese prepare large quantities of alum, with which India is chiefly supplied. Medicinally, it is valuable as an astringent, particularly for healing and hardening the gums.

Many of the clays yield a considerable quantity of alum in an efflorescence, by exposure to the air or the heat of a furnace, such as the sulphuretted clay of La Tolfa, in Italy, and the pyritaceous clay of Schwemsal, in Saxony.

Shale is another sort of bituminous clay, from which alum is easily procured by burning or calcining it in a furnace. There is a large bed of this near Whitby, employing many hands in the manufacture of alum. Few persons would ever have thought of alum being prepared from clay; but it is very interesting to know the history of the materials we use in ordinary life.

Edward and Alice thanked their father for his information, and professed themselves almost glad of the unexpected failure of their experiments, as it had led to his notice. But he told them he had some other interesting things to tell them about clay, if they were not tired of listening to him.

Oh, no, they said: they could listen all day.

He then described to them the clay-banks of the Hudson and New England rivers, with their curious balls of clay, which have excited the astonishment of geologists as well as of common travellers. These deposits are called post-tertiary clays, and are the last formations of this continent before the history of man commenced. They were deposited when the ocean covered all the Atlantic seaboard, or "tide-water country," as it is called in Virginia, and flowed in broad straits up the valleys of the Hudson, Mohawk, Connecticut and Housatonic Rivers into the valley of the St. Lawrence. At that time New England and New York must have been three great islands, like what Newfoundland and Anticosta are now.

When the continent slowly rose, the ocean retired to its present limits, but the clays it had deposited in these straits were carried up high into the air. As the land rose more in Canada than it did in New Jersey, these clay-beds are only fifty or sixty feet above the water-level in the neighbourhood of West Point and Newburgh, but are two hundred and fifty or three hundred feet above Lake Champlain at Burlington, and an equal height above water-level at Montreal. The rains have washed these clay hills into ravines and steep cliffs, in which the sand-martins build innumerable villages of holes; and sometimes there happen avalanches of sand and clay, which bury houses and people under them. Such a calamity happened a few years ago at Troy.

Out of these banks of clay the river-floods and rain-storms wash shells and the curious shapes of clay which induced me, said Mr. Goodman, to go into this long description. They are of every variety,—round as marbles or balls, egg-shaped, long pipe-like cylinders, dumb-bells, potato-formed, flat like plates, ring or quoit shaped, and sometimes showing some fine stem or piece of sand in the centre.

Great collections of them have been made; but no one has yet quite satisfactorily explained the manner of their formation. We only know that all clay seems to form itself, when permitted, into circular forms; and you can tell a rock that has a large quantity of clay in its composition, by the roundness of its corners, in a few months or years after it has been blasted or broken into sharp edges.

There is another remarkable circumstance connected with the ancient deposit of clay. I refer to the red clays of the formation underneath the coal, and to the red clays also which were deposited in the ancient valley of the Connecticut and in the ancient estuary of Newark and Morristown. These red clays are now red rocks; but they were once the shore of a shallow sea, on which the waves of the tide flowed up and down; for, when the rock is quarried, there are the marks which the waves have left; there are the marks of rain and hail drops on the once soft mud; there are thousands of tadpole-nests, or the nests of some small fish, such as you may see in the clear sandy bottoms of our present streams; and there are the footprints of over an hundred and twenty different kinds of worms, crabs, reptiles and birds, in lines so plainly marked that no doubt is left upon the mind that thousands of these creatures wandered to and fro upon that ancient shore, leaving their footsteps to be covered up and preserved by each returning tide. Some day I will take you to see the great collection of these tracks at Amherst. Meanwhile, come into my library, and I will show you the pictures of them in a noble book, which the State of Massachusetts has enabled Dr. Hitchcock to print, to show the world these wonders of the great Creator's goodness and skill.

I

CHAPTER V.

FLINT AND SAND.

THE grotto-building had sent many a party out to collect curiosities, and, combining business with pleasure, they carried their dinner with them and brought home their provision-baskets laden with shells or stones. Edward usually carried his geological hammer with him, and found ample work in breaking the rocks to pieces to discover their composition. Among their various parts he occasionally found nodules or balls of hornstone, or layers of flint, which excited his admiration by their glittering smoothness and the sharp edges which the broken pieces had. He thought that they might be even used for knives in cases of necessity; and he remembered having seen such used in old flint-lock guns.

His father told him that in the interior of the country there were places where finer qualities of these flints had been quarried, so to speak, by the Indians, long before the arrival of white men; and the farmers find, in ploughing near such places, multitudes of broken pieces and chips of flint, and perfect arrow-heads and knives; for the natives had no knowledge of iron, or could not make it. In England and France there are many similar places; and the museums of Europe are full of specimens of the skill of the aboriginal tribes of men inhabiting the country before the cultivated Greeks and Romans came among them from the East and South. In fact, it seems as if all men at first used flint, and afterwards copper hardened with a little tin, and finally iron. The Egyptian priests, like the Mexican priests, sacrificed with sharp black stones for knives,—made of a sort of volcanic flint called obsidian. The barrows or mound-graves of Sweden and Norway, when opened by antiquaries, yield many articles of stone buried with the kings and warriors whose skeletons are found in them. And it is said there have been found such implements at the bottom of the gravel-beds of Picardy in France, mixed with the bones of extinct animals. Flint, therefore, has been an important aid to man.

"Tell us," said Mr. Goodman, one day, turning to Edward's uncle, who had come over from England to visit them, and was admiring their little grotto, to the great delight of the children,—"tell us about the chalk cliffs of Dover, and the rows of round flint stones which I remember to have once seen in them when crossing the English Channel to Calais. If I recollect right, they lie in regular rows one above another, and, when the waves dash against the bottom of the cliffs, the chalk falls down and the balls of flint roll out and are tossed about upon the shore."

"Yes," replied the uncle: "I have noticed in my travels that the internal composition of hills can be usually discovered by their outward shapes,—especially where they are under the influence of the powerful destroying agency of water. Clay-rock hills are usually of a soft, rounded aspect, while sand-rocks form sharp ridges. Chalk cliffs are cut straight down, with beetling heights overlooking the sea; and the two shores of Dover and Calais face each other in such a way that no one doubts that the chalk once stretched across the channel, but has since been broken through and washed away by the currents of the sea. Here is a picture which, at the left

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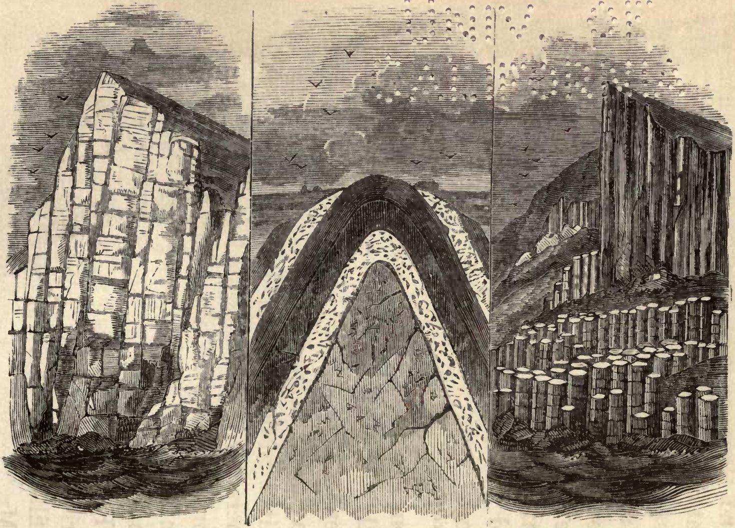

DIFFERENT KINDS OF COAST FORMATION.

Opp. p. 133.

hand, shows these cliffs of chalk. The right hand shows a very different kind of shore,—that of the north of Ireland, where an ancient lava current has made the celebrated Giants' Causeway. The middle division of the picture shows how the rocks are often bent so that the lowest layers rise in the middle higher than the layers which are really above them; and this sometimes shows itself on the seashore.

"The flint balls in the chalk are all separated from each other, and no two of them are exactly alike. I have frequently broken them open with my hammer: some are white, others gray or black, many are hollow, and contain a little water, or some bright crystals, while others exhibit substances looking like bits of sponge, shells, or other matters,—their only general resemblance being the white cherty crust which envelopes all. When I was last in England, I selected the prettiest and most curious I could find; and you shall have them to fill up the vacant places in your grotto."

Mr. Goodman then explained that flints consisted almost entirely of silex or silica, which is an oxide of the base silicium or silicon. How they got among chalk cliffs in such regular lines, yet each one lying quite separately from all the rest, is something for the chemist to explain. It is known that natural hot springs often contain silica in solution,—that is, dissolved or melted,—and that as the water is evaporated, or as the silica sinks to the bottom, it gradually encrusts every thing in its way, or hardens into nodules such as these flint stones; but how it leaves the chalk so pure and dry is very hard to understand. Its texture is so close and even that some have fancied that flint must have been originally in a state like jelly.

Flint seldom forms entire rocks, or veins of rock, and never assumes any regular crystallized shapes. It sometimes occurs in rolled pieces, like tubes, with a hole through. Flints are common in every part of the world and in all sorts of mountains. Among those which seem to be the oldest, they appear in the veins of metal, but they are most abundant in chalk. When rubbed together in the dark, they phosphoresce, or give out light and heat, and emit a peculiar smell. They are very hard, but doubtless could be cut and carved; for on the ancient abbey-gates of Canterbury and Colchester, in England, are some ornaments of cut flint; and it is occasionally squared and used for paving observatories, instead of slate or lead: it is, however, more commonly powdered, or ground, for modern use. In the county of Sussex, England, there are many houses and churches built of flint; and very substantial they look even now, although they have been standing many years. Where they are plentiful, flint pebbles are still used for building, as they hold mortar firmly, and really look pretty. They are very durable, unless fire is applied,—when they calcine and powder. Several of the precious stones named in the book of the Revelation as the foundations of the New Jerusalem are varieties of silica or flint, symbolizing their durability and strength. I have already spoken of the arrow-points and spear-heads of the ancient Britons, specimens of which turn up in various parts of England and Wales.

"Do they not break very easily? I broke several with my hammer," said Edward.

"Yes; because you had just taken them from the quarry, or the chalk-bed in which they were deposited: they were, therefore, brittle, as well as moist; but they dry quickly, and, when dry, assume their well-known hard and refractory qualities."

Flints, Mr. Goodman stated, so very generally have a cavity inside, or enclose the remains of sponges, shells and marine zoophytes, that it is highly probable they are merely an aggregation or collection of silex around a nucleus of some organic substance, which has accumulated so gradually and gently that the shape of the delicate structure inside has been completely preserved, as may be seen with a magnifying-glass in some of those brought home. Thin slices of flint from many localities have been examined by the microscope, and all exhibit a similar network of fibrous appearance, much like that of a thin slice of sponge. Those beautiful fossil woods brought from Antigua are composed almost entirely of silica, so thoroughly introduced into all the pores of the trees that their former grain can be distinctly perceived, so as to be named by any carpenter. When shown to one, he called one of those pieces oak, and another maple; but the crystalline part in the large veins does certainly look very like the inside of the flints from the cliffs. These crystalline portions would also burn to powder in the fire, no doubt, though the powder of the fossil wood would probably show its colouring-matter.

Some of these pieces of fossil wood would look very pretty sliced and polished, and would then be termed chalcedonies, or agates. They are often beautifully marked in regular lines, and are therefore called fortification, ribbon, or moss agates: indeed, they are most highly valued when the internal figure resembles some animal or plant.

M. Brogniart examined a large number of moss agates, to discover some certain evidence that the enclosed forms were really vegetable; but he came to the conclusion that they were all due to an arborescent crystallization of some metal, such as manganese or iron. But lately agates have been found which seem to show true branches and leaves of vegetables.

The name "chalcedony" is derived from the city of Chalcedon, in Asia Minor, where this form of flint was found in ancient times. The best spectacle and opera glasses are of rock crystal, which is the purest form of silica, so transparent and so hard that they will bear cutting into thin slices and polishing. They not only magnify better than artificial glass, but cannot be scratched so readily, while they are cooler and more pleasant to the eye.

The uses of flints are very various: the white flints, most abundant at Swanscombe, near Gravesend, England, are ground for the best china-ware and finest flint-glass. Before the invention of lucifer matches and percussion-caps, they were as indispensable to the housewife's tinder-box as to the sportsman's gun. They are used, too, for some diseases of horses' eyes. Most sands, and sandstones, consist so entirely of silica that they ought to be classed with flints, though sandstone is a hard rock and flints are always in separate nodules. Careful examination will show that common sandstone consists of minute particles of silica cemented by argillaceous or clayey earth. It is soft at first, like the new red sandstone rocks in Staffordshire, but in the lapse of years it becomes extremely hard, forming the free-stone used for paving and building. These particles of silica are actually rolled and rounded rock crystals, formed by the slow breaking up and wearing away of granite or other crystalline rocks of a more ancient date. The Paris building-stone, the Caen stone, the Portland stone, the Pictou stone of Nova Scotia, and the Norristown and Newark red sandstones are instances of building-material which hardens after use.

So many substances have silica mingling with them in various proportions that it must be regarded as one of the most important of earth's treasures, and is found scattered everywhere. In fact, one-half of the whole crust of the globe is made of it. It enters into all rocks, and, of course, into all soils. Many vegetables owe their strength to the silica they imbibe from the earth. The grasses especially require for their healthy growth a large proportion of silica; and it is this substance which renders their slender stalks so strong and stiff. This has been shown by actual experiment; for a bead of silex as transparent as glass has been extracted from grass by a blow-pipe. Moreover, when a stack of hay in a meadow, between Mannheim and Heidelberg, in Germany, was set on fire by lightning, and entirely consumed, the silex which remained was found in a melted mass upon the ground. It looked somewhat like glass, and was at first supposed to be the product of a meteor, but, when chemically tested, proved to be silica combined with potash, just as it usually exists in grass. That substance was in reality the ashes of the hay; and the ashes of burned corn, sugarcane and bamboo, all of which are varieties of grass, generally consist principally of minute particles of flint. Some reeds will strike fire; others are used as rasps by artists, especially in finishing plaster busts or ornaments. Some kinds of polishing-powder are made up of the minute sandy shields of microscopic animals. But silica seldom exists in animals, and then only in consequence of disease.

The best millstones are made from a rock which is almost pure silica, called burrstone, full of cavities or blisters, tinted with iron, and exceeding hard. Finer kinds are used for grindstones, and still finer for whetstones, by glass-cutters and cutlers. Silicious or flinty sand is used also for the beds in which iron, brass and other metals are cast, equalizing the heat of the china-kiln or potter's oven. The chemist uses it to make his sand-bath, which heats slowly and retains a uniform temperature for a long time. It will, however, melt entirely under very great heat, as we find upon examining volcanic productions.

Indeed, silica mingles largely with the basalt, greenstone, hornblende, trap, granite and serpentine of those rocks which are said to be of igneous origin,—that is, which were once in the condition of boiling fluids, like the lava of burning mountains.

Many of these igneous rocks much resemble various modern volcanic productions. Though the granite and basalt rocks do not exhibit any evidences of cones and craters, like the burning mountains of the present day, yet veins of granite occur shooting upwards so vertically through every stratum of rock in various parts of the world, that volcanic eruptions alone seem to account for them. But some of these rocks were perhaps made pasty by water and a gentle heat, and slowly pressed up through cracks by the weight of the rocks above them. Such has been the case sometimes with limestone, and even with coal. As the earth seems to be still gradually cooling, the water of ancient times may have held much more silica in solution than is common now, as we only find it in hot springs, around which it is deposited so constantly that petrifactions abound around them, especially in Iceland, where the Geysers are ornamented with mosses and grasses so incrusted with silica that the original vegetable has entirely disappeared, leaving only its semblance in delicate crystal, or frosted stone-work, looking very beautiful.

Stems of a soft and succulent nature are found preserved in flint; and even the young leaves of a palm-tree just about to shoot forth have been discovered completely silicified. The process is difficult to understand; but it has occurred in innumerable instances, in all ages of the world and in all kinds of rocks. We may see at the glass-works how completely foreign substances can be enclosed in melted matter, and then vitrified,—as those elegant French glass letter-weights enclose bunches of artificial flowers, or the silver crest is put into those pretty dessert-plates we saw one day being made there.

The polishing-stone called Tripoli consists almost entirely of silicious or flinty matter,—which has originated, as the microscope shows us, from the shells or shields of animalculæ long since extinct. With a powerful magnifier, many thousands of these shells are still distinguishable in a cubic inch of Tripoli. At a meeting of the British Association, Professor

Ehrenberg exhibited a large glass full of silicious or flinty earth, which he had prepared from animalculæ now existing.

Silex is certainly the most abundant substance on our globe; for it is proved by analysis to form two-thirds of all the minerals yet examined, including some of the hardest gems and softest clays. It is the most plentiful ingredient of the oldest rocks, but mingles also in various proportions with the rocks of every age and every variety. The felspars contain about one-half silica and one-third alumina; and with the addition of portions of lime, potash, soda, or oxide of iron, they produce the beautiful crystalline substances with golden specks, known as sunstone, moonstone, and ice-spar.*

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* "Musical Sand."—Hugh Miller tells us that he observed that the loose Oolitic sand of the Bay of Laig, in the Isle of Eigg, Hebrides, yields a sonorous sound—sometimes a musical note—to the tread, especially when pressed obliquely in the step. In its drier tracts this sound is obvious only during calm weather at a distance of twenty or thirty yards; but where damp ground exists beneath the surface, and the dry sand lies above, the tones are louder and sharper.

Similar sounds have been observed for ages on Jebel Nakous, or "the Mountain of the Bell," about three

Every one has noticed the musical sound of wheels in the dry sands of the Jersey pines,

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miles from the Gulf of Suez, "resembling the low tones of an Æolian harp, and occasionally the striking of a clock, or the notes produced by drawing moistened fingers over glass, or even the rumbling of distant thunder," when a large extent of this sand was agitated.

About forty miles north of Cabul, near the base of the Hindoo Koosh Mountains, is the hill of Reg Rawan, or "Moving Sand," which, when disturbed by people sliding down it, emits sounds "resembling those issuing from drums and nagarats,"—a phenomenon which attracted the notice of the natives at a very early period. Both Hindoos and Arabs have characteristic superstitions to explain these curious facts; but they still puzzle the more scientific inquirers of the present day. The sands of these three localities, in Scotland, Arabia and Cabul, are similar, though not precisely identical, in composition. At the Bay of Laig, Hugh Miller perceived "that the loudest sounds were elicited by drawing the hand slowly through the incoherent mass in a segment of a circle at the full stretch of the arm, and that the vibrations which produce them communicate a peculiar titillating sensation to the hand or foot by which they are elicited, extending in the foot to the knee, and in the hand to the elbow." In 1832, M. Seetzen, a German, and Mr. Grey, of University College, Oxford, were the only Europeans who had visited Jebel Nakous, the Mountain of the Bell. Lieutenant Welsted, of the Indian Navy, afterwards carefully explored the mountain, and gave a fine lithograph of it in his Travels; and, in or the coarse white sands which cover the top of the Broad Mountain in the anthracite coal-region.

1837, Sir Alexander Barnes visited the Indian "Moving Sand."

See "The Cruise of the Betsy," page 59; Sir J. Herschel's "Treatise on Sound;" "North British Review," March 31, 1845.

In the United States such musical sand may be heard and gathered at Tiverton, near Newport, in Rhode Island.

CHAPTER VI.

GRAVEL.

THE pretty, bright, yellow-coloured gravel, which looks so cheerful and furnishes such pretty paths in our gardens, is not to be found everywhere; and therefore, when Edward visited some friends at a distance, he was much struck with its appearance, and, as usual, brought home some specimens and endeavoured to find out its origin and composition. Mr. Goodman noticed his studies; but having early inculcated the maxim, "Read and you will know,"* that his children might exercise their own minds, he left him for a time to his own researches among dictionaries and encyclopedias, without making any remark.

Poor Edward, however, found that these learned compilations did not solve many of his inquiries: indeed, some of these works were as entirely silent upon the word "gravel" as if no such compound existed. At length he sought his father's aid; and, having spread out his samples on the grotto-table, he called his brothers and sisters to join them, and related his unsuccessful efforts to obtain information for himself upon the subject.

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* From the mother of the celebrated Sir William Jones.

Mr. Goodman told him that he had not looked under the right head for information; for that "gravel," though the common name, is not a scientific appellation, and therefore not used by the learned in technical works upon mineralogy. They generally term it *alluvium*, *diluvium*, or *detritus*,—though, as seen in some large gravel-pits in Kent, England, it was natural to suppose it to be a regular form of rock. It is found collected into certain localities; but, if examined, it will easily be perceived that it consists of various sorts of stones broken into fragments and then rounded by continual rubbing together and rolling about. When broken with the hammer, some of these stones are exactly like flint inside, often yellow; others are white like quartz, or red like cornelian, gray like slate, and even variegated with stripes or spots like the agates of which brooches are made. In fact, gravel is composed of rounded pieces of every sort of hard rock over which the water flows which forms the river in the bed of which it is found. If two of the purest-looking white stones from a gravel-pit be rubbed together very hard in the dark, they will soon be seen to look almost red-hot, while they emit a peculiar smell of burning, and some degree of heat. These stones are common amid shingle-beaches; and children by the sea-side often pick them up and amuse themselves by rubbing them together as "fire-stones," from their aspect and effluvium. Shingle generally has a gray tint, and gravel a yellow hue; and though the latter is found quite inland, and the former on the coast, both have been rounded and deposited much in the same way, and both bear the same general name of alluvium, from the Latin word *alluo*, signifying to wash, indicating the fact of its having been washed into valleys or hollow basins by water afterwards drained away, or evaporating into the atmosphere.

GRAVEL evidently has originated from the ruin of other rocks, caused by the action of the atmosphere, or rain and frost, upon such rocks as are or have been exposed to the effects of weather; for it is found chiefly on or near the surface of the earth. Gravel-beds among lower rocks most probably originated in the same way, when such rocks were on what was then the surface of the earth. In the midland counties of England there are vast accumulations of gravel, composed of fragments of nearly every sort of rock existing in the country. They are many fathoms deep in some places, and in others so heaped up as to form decided hills. They are so extensive that English geologists say that from Leicester to Lutterworth the traveller passes for forty miles over one continuous gravel-bed. All round this region there are other large and distinct gravel-beds, and many hills crowned with it where other substances intervene. But this is nothing to the great accumulations of gravel in the northern regions of our country, especially in the central table-lands and valleys of the Rocky Mountains, where the emigrant trains wander for weeks over a gravel desert formed from the mountain peaks and ranges, which appear at intervals as if thrust up through them from below.

The arctic regions are covered with gravel, among which occur large boulders, or wandering rocks, brought to their places by ancient icebergs when the ocean was above the land. And this "drift" gravel, or "diluvium," as geologists call it, comes down to about the latitude of 40° or 41° in the Northern United States,—covering even the highest parts of the Green Mountains of Vermont to a depth of one or two hundred feet.

Whole cabinets of rocks can be collected out of the gravel. It is asserted by English geologists that specimens of nearly a complete series of British rocks might be obtained from the gravel in the valley of Shipston-on-Stour, near Market Harborough. Large boulders, or round masses of granite, porphyry and other materials, are found scattered over the plains of Germany and Russia, so far from their native mountain-beds that they must have come across the Baltic when frozen fast in the bottom of floating icebergs from the glaciers of Norway and Sweden. Similar rocks belonging to the Alps are found lying on the sides of the Jura Mountains, having come on ice-glaciers fifty miles across the valley of Switzerland.

Besides these comparatively modern gravel-beds, there are ancient beds of hardened gravel often forced up into nearly vertical positions by some convulsion of nature: they are called conglomerates, breccia, or pudding-stone. In these the gravel is cemented by some other substance, such as clay, silex or lime. In pudding-stone the fragments are round, and coloured much like the English Christmas pudding. In breccia the fragments are angular. The conglomerate under the coal-measures is such an ancient gravel, but probably made by the sea-waves upon an ancient beach.

The gravel outside the chalk-basin around London consists principally of flints, from which the chalk, as the lighter substance, was carried away in the subsidence of the waters. The gravel-beds of Philadelphia consist of the rounded ruins of the rocks of Chestnut Hill, Fairmount and Gray's Ferry. Under the microscope it is plainly seen that sand consists of flinty materials broken up into still smaller fragments. Sometimes one material predominates, or some metallic oxide mixes with it, producing the various-coloured sands of which cliffs, such as those at Fall River, Providence and other New England places, are composed. Flint sand is valued for its vitrifying or glazing qualities.

Sand lines the shores and forms the beds of most rivers, from the gradual accumulation of alluvial deposit from the land through which they pass. The river-floods carry a great deal out at their mouths to the sea, so as by degrees to extend the shores. Thus, in the Lake of Geneva the Rhone has formed a delta two miles long and nine hundred feet thick, during the last eight hundred years; and another delta has been formed by the same river on the shores of the Mediterranean Sea, which has now become a solid limestone rock.

Alice asked what the delta of a river was.

Mr. Goodman explained that the heap of sand, mud or gravel which gradually accumulates at its mouth sometimes takes a three-cornered shape, resembling the Greek letter delta, (*Δ*,) and is thence called by its name. The formation of a delta at the mouth of any tiny rivulet which flows into a stagnant pool may be watched, and many interesting facts in physical geography may be learned from such an amusement. The delta of the Mississippi has advanced several leagues since the city of New Orleans was built at the mouth of the river, and, not having had time to drain, or dry by evaporation, it is still the "dismal swamp." During two thousand years the land has gained at the mouth of the river Po eighteen miles, extending also on either side one hundred miles along the coast.

History mentions the condition of many rivers at different periods, and modern science can judge of the Mississippi by examining the locality, the evidence of fresh deposits is so clear. Thus, the delta of the Ganges begins two hundred and twenty miles away from the sea, while the waters of the ocean are made muddy by the matter carried out for sixty miles from the shore. The delta of the Niger extends so far every way as to form an area of twenty-five thousand square miles. The immense alluvium still depositing by the rivers Amazon and Orinoco is chiefly swept away by the Gulf Stream in a northerly direction. The waters of the Amazon show this so distinctly that they can be distinguished from the ocean three hundred miles from the coast.

The quantity of sediment brought down by the river Ganges every year amounts to more than six thousand millions of tons,—sixty times the estimated weight of the great pyramid of Egypt. This at first sight appears impossible: yet it will be credible on considering the very careful experiments that were made to ascertain how much solid matter was carried past one city by a single river in a year.

By careful watching for a fixed period, Dr. Dana found that the river Merrimack, in Massachusetts, carried past the city of Lowell, in the year 1838, so much, that if all the sediment had been anthracite coal, such as is used in the Lowell print-works, there would have been an annual supply of five thousand tons for one hundred and ninety-seven years. The Ganges is a much larger river, possessing many mouths: so that, if one river carried down so much past a single point, it is not surprising that the Ganges should deposit at its mouth a much greater quantity. This amazing amount of sediment, or alluvium, to be exact, finds its way into these rivers by means of heat, cold, and water in its various conditions of fluid, ice and steam, all helping the process of breaking up soil and rock,—sometimes acting separately, sometimes conjointly. Thus, the heat of the sun continually crumbles up the surface of the earth. The most casual observer must have noticed how the soil dries to powder in the sunshine during very warm weather; and we read of the same effect in Iceland from the heat under ground near Mount Hecla.

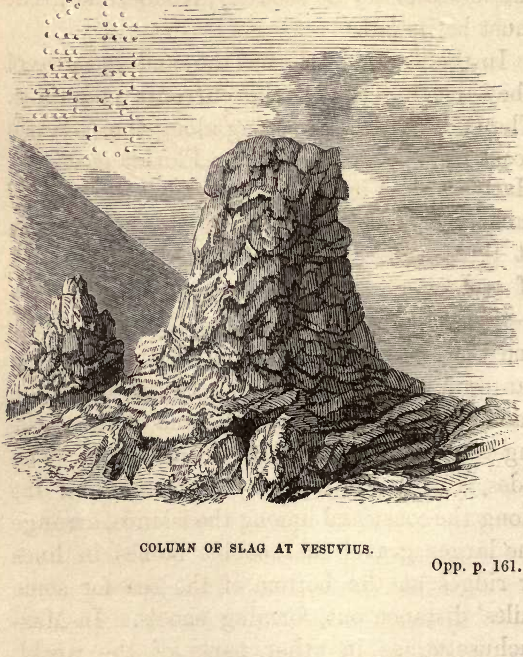
When rain comes, this powder is easily washed down into the mountain-streams, which, rushing along some steep descent, wear away harder rocks. The same thing is accomplished by "ice-freshets." It is impossible for any one who has not witnessed the breaking up of one of these frozen streams in the spring—when for many miles the whole channel becomes literally choked with ice—to form an adequate idea of the immense excavating force it exerts, scooping out huge caves, and whirling round hollows, so that the approach of such a laden torrent is justly dreaded both by man and beast. It must be remembered that most rocks lose one-third of their weight in water, and when ice is frozen round them they are easily moved.

Water is a powerful agent in producing gravel and sand, as it acts upon hard rocks both chemically and mechanically. Chemically, it dissolves some of the substances they contain and renders the mass loose and porous; mechanically, it gets between the particles and forces them asunder, so that they are more easily worn away by any current passing over them. Then, as water expands in freezing, frosts still more effectually separate the fragments, till year after year this gradually prepares abundant material for torrents to carry off to the gravel-bed, or for land-slips.

At Dover the chalk cliffs are perpetually giving way, from the sea undermining them below, or the frost detaching large masses from above, which occasionally do much damage in their fall. Two ladies, on one occasion, had been quietly resting in a large cave only one-quarter of an hour before it was filled up by a mass of many tons' weight, which fell with a noise resembling distant thunder. Their father had heard the noise, and, knowing their habits, went to seek them; and they all returned to the scene of devastation, feeling deep gratitude to God, who had preserved them from a danger that they had not contemplated. Truly, we may rejoice that "he is ever about our paths." In the churchyard of the same town, a tombstone still tells of a whole family killed by a mass of chalk cliff, which crushed the house and filled up the garden, like the avalanches we read of in the Alps, composed of snow mixed with detached earth and stones and ice. They are often much larger than our land-slips, so as to bury several villages and thousands of people in a moment. The glaciers are rivers of ice resting in the higher valleys of mountain regions and slowly flowing down towards the lower valleys, where they continually melt and a river of cold water flows from a cavern at the end, while all the rocks which have fallen from the mountain-sides upon the ice in the bed of the valley are carried down upon its back and tumbled off, one by one, at its end, forming piles of rubbish, sometimes hundreds of feet high, called "terminal moraines." As the ice-river slowly moves along around the points of the mountain-sides, it cracks and gapes in hideous crevasses, down which the stones fall; but, as the surface of the glacier is always melting, these stones re-appear a mile or two farther on. As they protect the ice with their shadow, they are soon mounted on pedestals of ice, which get so high at last that they melt through and the stone falls down again. Thus these rocks are forever falling into the cracks of the ice and mounting on pedestals of ice, until, after many years, they get to the end of their journey, and tumble over the edge of the glacier into the valley below. At the bottom and sides of the glacier, fragments of rock and pebbles frozen into it produce the effects of a huge rasp, crushing and grinding every thing over which it passes, and scratching the harder rocks in every direction, as travellers may easily perceive. The glaciers of Viesch, Aletsch and others in the Alps, are full of fragments of rock which are perpetually preparing gravel.

From all these causes it may be easily understood how sand and gravel come on the land and the sea-beach, and, when it is carried out to sea, how in time it fills up parts of the ocean and forms new land. Accordingly, we find this is the case not only at the mouths of rivers, but on coasts where the wind blows chiefly on shore or where currents set one way. The waves wash up immense quantities of sand and gravel, so as to fill up harbours or raise a bar across them. The waves, in a single storm, are sometimes so powerful as to wash up large boulders, which lie in a row on the shore. These form rather a protection against future storms,—as we are told in the Bible that God himself "placed the sand for the bound of the sea by a perpetual decree, that it cannot pass it: and though the waves thereof toss themselves, yet can they not prevail; though they roar, yet can they not pass over it." (Jer. v. 22.) Extraordinary tides often carry sand and gravel too high on the beach to be reached by the usual tides: this leaves time for the sand to dry, and, being carried inland by every favourable sea-breeze,—land-winds being too feeble to send it back again,—the sand falls, and gradually becomes a formidable enemy, overwhelming fertile fields, filling up rivers and burying villages. Hence the dunes, or downs, common in every part of the world, and of which we will speak again by-and-by. In Michigan there are ranges of sand-hills along the shores of the great lakes from one to two hundred feet in height. The sands of the Libyan Desert, driven by the west wind, have encroached upon the valley of the Nile so as to cover over the ancient cities of Egypt and half bury up the greatest temples that men have ever erected. Belzoni and the

French, English and Prussian savans who followed him in his explorations, have uncovered a multitude of temples, rock tombs and statues from the sand, which has protected these remains of a remote antiquity from destruction, and thus enabled us to read the history of the oldest civilization the world has ever seen. The whole west side of the Nile has been rendered one vast, barren waste, except in a few sheltered spots known as oases. That these wastes were once populous is evident from the numerous remains of ancient temples, palaces, cities and villages still to be found there. Light as the sand-grains are, each by itself and carried by the wind, yet so heavy do they weigh when all combined that their accumulation has proved an effectual weapon of God's wrath in burying the rebellious cities of Babylon, Nineveh and others, whose very names would be lost but for their record in the roll of the prophet, whose messages of mercy to the penitent were despised and laughed at in the days of prosperity. As a foundation it is so unstable that our Lord compares the careless hearer of his word to a foolish man building his house upon the sand,—resting his soul for



COLUMN OF SLAG AT VESUVIUS.

Opp. p. 161.

peace, perhaps, on temporal prosperity. But when the rain of God's wrath descends, and the wind of his scrutiny blows, and beats upon the house to try its security, it falls, and great must be its fall.

In the waters of the sea the sand and gravel obey the direction of the currents and tides. The Gulf Stream, sweeping along the Atlantic coast from between Cuba and Florida past Cape Hatteras, in Virginia, and Cape Cod, in Massachusetts, turns all the sand-bars which form at the mouths of our rivers and at the ends of our bays into hooks, towards the north, —such as Paulus Hook and Marcus Hook, and Cape Cod itself, the end of which, as you can see upon the map, curls round upon the harbour of Hingham like the end of the sucking-tube or proboscis of a butterfly. The tides, rushing every day twice to and fro along the coast and among the islands, arrange the larger gravel and cobble stones in lines or ridges at the bottom of the sea for some miles' distance out, forming shoals. In Massachusetts, as in other parts of the world, such long and regular hills of gravel, called "osars" in Sweden, are seen upon the dry land back from the coast. This is one of the proofs we have that the land has risen out of the sea in former times.

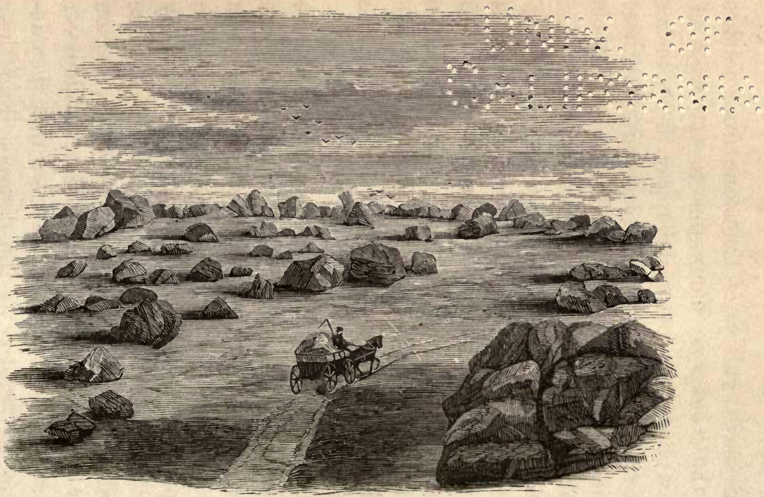
The struggle between the sand of the sea and the cultivated fields of the farmer goes on everywhere. The people who live along Cape Cod have their farms continually strewn with sand. In England, there is a part of the Channel off the coast of Kent called the Downs, a roadstead quite in the sea; and these Downs were formerly land, overwhelmed first by sand, and now by sea. The Goodwin Sands, lying outside or eastward of the Downs, were actually part of Earl Godwin's landed estates within a comparatively recent period, and are still dry at every low tide.

All around the Bay of Biscay a similar encroachment is going on. Numbers of villages have already been destroyed, and towns are now threatened by sand-hills moving towards them at the rate of sixty or seventy feet annually. In Cornwall, the church and village of Piran Zabuloe were buried so long ago as to have left no records but the ruins of the church itself and the traditions preserved in the neighbourhood.

These gradual deposits of sand often alter the course of rivers: thus, in the short space of eleven years, the head of the river Jellinghi, in India, was removed three-quarters of a mile farther down. The junction of the river Cosa (as large as the Rhine) with the Ganges has been moved forty-five miles.

The waves of the sea must be very powerful; for the bar of shingle at Dover Harbour comes back every tide, notwithstanding all the pains that are taken to wash it away by sluices. On this account an officer is always appointed to watch the mouth of the harbour, and guide vessels in, as the shape and direction, as well as the height, of the bar, are perpetually changing. The waves of the ocean are irresistible when driven by a furious wind. The granite blocks built into the foundations of the breakwater at Cape Henlopen, at the mouth of Delaware Bay, were tossed about during a great storm in the wildest disorder. And when the Plymouth Breakwater, in England, was being constructed, some heavy gales occurred, during which huge blocks of granite and limestone, weighing from two to five tons each, were washed about like pebbles. Three hundred such were borne a distance of two hundred feet, and even up the inclined plane of the breakwater. Some were carried quite over it, and scattered in all directions; and one block, weighing seven tons, was carried one hundred and fifty feet: so that it is no wonder that sand and gravel should be carried about by the wind and waves together.

The changes made by floods of the present day on the surface of the land suggest that many of the peculiarities of different countries have had a similar origin. For example, accumulations of drift, found in many hilly regions far from the sea, consist of sand, gravel, and even large masses or boulders brought some distance from the gravel-pits, and sand-hills, or rocky mountains to which they belong. Boulders seem to have drifted from the north several hundred miles in a southerly direction, and to have been carried beyond mountains one or two thousand feet high, as in Massachusetts, Maine and Nova Scotia. There are boulders which have been torn from the Green Mountains of Vermont, now lying high up upon the flanks of the White Mountains of New Hampshire. Each of the mountain-ridges of New England furnishes boulders for the country to the south-east of it. In Eastern New York there are trains of boulders running in nearly straight



BOULDERS ON A PLAIN.

Opp. p. 165.

lines across valleys of limestone from notches in the sandstone mountains to the west of them; and some geologists suppose these notches to have been made by great icebergs, and these trains of boulders by great eddies or whirlpools behind them. On the Highlands west of the Hudson, in Orange county, great boulders of gneiss are to be seen laid, as if by the hands of man, upon smaller stones of limestone full of shells, which must have come up from the valleys lying to the north. How this delicate operation has been performed is one of the secrets of nature.

In Europe, the Netherlands, Denmark, the plains of Germany, Poland and Russia, are strewed over with boulders and pebbles, which can be traced to their parent rocks in Sweden, Lapland and Finland, in which countries they are still more numerous. To reach these localities they must have crossed the region now occupied by the Baltic Sea. Wherever there are boulders it is observed that they decrease in quantity as the distance from their former homes increases. Near Beyrout, in Syria, at the foot of the Himalaya Mountains, in India, and near Mount Atlas, in Africa, similar boulders are observed, which have somehow or other wandered from their native regions, just as the drift-wood from warmer countries is now carried to the shores of the arctic regions by ocean-currents, for the benefit of the Esquimaux, who could otherwise procure no wood. The largest proportion of the Northern hemisphere is covered with a crust of sand, gravel and boulders varying in thickness from a few inches to two hundred feet; and scarcely any mountains are entirely free from this geological drift: sometimes very large blocks are poised upon their summits.

In Switzerland, some of the largest blocks which have crossed from the Alps over to the Jura lie curiously poised upon peaks. This was accounted for on the supposition that they had been placed there by men; but a different cause has been suggested, which supposes them to have come over upon the surface of ice; and a learned geologist has explained how the sun's rays would heat the rock of the peak, and melt a funnel through the ice above it, down into the centre of which would slide any boulder which happened to be near enough upon the ice, and would, of course, settle precisely upon the peak. In New England, all the surface-rocks which peep above the soil and the covering of drift are rounded, polished and scratched by the boulders when they were moving to their present places. These boulders are of every size. The word signifies a large round stone that could be *bowled* along by a sufficient force; and therefore a fixed rock ought not to be so called. Boulders differ in weight: the one used as a pedestal for the equestrian statue of Peter the Great at Petersburgh weighs fifteen hundred tons, but weighed much more before the artist had the bad taste to cut it down from its original native form to an artificial shape, which he thought finer, but which has in fact destroyed much of its sublimity. It was brought over marshes nearly a hundred miles, on cannon-balls for wheels, over a road made expressly for the occasion,—and reminds us of the moving, in ancient days, of those great obelisks and statues of one stone from the Egyptian quarries. to the cities along the Nile. Some boulders are called rocking stones, when, as seems most probable, streams of water have removed the sand and gravel which accompanied them, and they remain poised so evenly upon a single point that the slightest touch will set them rocking. Such are termed, in England, logging or Logan stones, and are not uncommon in Cornwall; and very large ones are found in Massachusetts. Another name for them in the south of England is Ambrose stones; and in that and many other countries ignorant people say that they were giants, turned into rocks for their wickedness. Stories of this kind are common as far east as Persia.

Sand and gravel are more frequently found in valleys. This would be expected, from their being produced by water wearing away rocks and then carrying the detached pieces to their destination by storms or torrents; and so it is really found to be. In the valleys of the Alps, and especially near the gorges, defiles, or openings from one valley into another, sand and gravel accumulate into mounds and ridges,—straight, curved and crooked,—called moraines, as I have explained before. But in the true drift we see successive strata, or layers, of sand, gravel and clay, as if floods had occurred at different times, each leaving sediment behind it. Occasionally, beds of gravel are found resting upon successive beds of lava, each exhibiting evidence of a different and older age than those above it; and in such cases the gravel consists partly of fragments of lava torn from the beds below. Such "volcanic breccias," as they are called, are common in Auvergne, in Central France. Among the oldest rocks are similar conglomerates and breccias, proving that the same laws of destruction and re-formation have always operated which we see performing all these wonders in our own day. And the most gigantic marks of destruction show the goodness of God; for thus the earth has been prepared for the use and happiness of man. It is this universal tearing to pieces of the rocks, and distribution of their sand and clay in loams of all kind, that has made most of the earth's surface so fertile. The hard surfaces of marble, granite and flint are perfectly barren till the surface is broken up or mouldered by the atmosphere sufficiently to hold moisture. The very fertile spots are generally where one soil joins another, so as to mingle together. And the most fertile of all are where all the ingredients of all the rocks are combined, in the rich bottom-lands of modern river-valleys, or in the black soil of the steppes of Southern Russia, the pampas of South America or the prairies of our West.

CHAPTER VII.

CHALK — CORAL — MAGNESIA — ASBESTOS — MOULD.

THERE is no true chalk in America,—although we have the so-called "cretaceous" or chalk formation all along the Atlantic seaboard and on both sides of the Rocky Mountains. So, when the subject of the nature of chalk was broached, in one of their conversations in the grotto, by Edward,—as he stood scraping a piece with his knife and catching the soft, white powder on a newspaper, while he picked out small specks of flint or crystals of silex from it now and then, and wondered how they came there,—he called upon his uncle to explain. For, like most things with which we are familiar from infancy, chalk had never excited Edward's attention, till, when old enough to travel, he had observed its absence from the rocks which he was accustomed to see and examine in his daily walks.

He began, therefore, to examine it more particularly, and to try various experiments with the largest blocks of it he could get, in moulding and cutting it into shape, but soon found it was too soft for such purposes. He marvelled that, with all the pains he took, his little chalk bridges and houses were washed away by the rain, or crumbled and were blown away during hot weather and high winds. He had heard his uncle say that, in the parts of England and France where chalk is the common rock and forms the soil of the country, the roads look as white as if covered with snow, while the short grass on the hills appears powdered with flour. In winter the mud is white, and in summer the dust wears the same hue,—which nevertheless soils all coloured dress and furniture as much as dirtier substances would. Huge masses are detached from the cliffs whenever heavy rains or long frosts prevail, while chalk-pits abound in the neighbourhood for supplying the demands of commerce. He wondered how these chalk cliffs and hills could have stood for so many ages, and that the fortifications of cities—Dover, for example—could be built of chalk, and stand in spite of rain and wind.

"No," said his uncle: "you are wrong there. For these cliffs do not stand firmly when exposed to the influence of weather. It may be seen how perpetually they are giving way, and changing their shape by the fall of large masses: it is only where protected by the intertwining fibres of short, grassy turf that chalk seems to hold together at all; and the outside chalk of the fortifications is protected in the same manner. The fortifications themselves consist really of solid masonry, which is only covered with chalk to break, as with a soft cushion, the force of cannon-balls."

"But what is the material of chalk?" asked Edward; "and is it an old rock?" For he had come to know that in the geology of the earth there was a great difference in the age of the rocks.

"Chalk," replied his father, "has received much attention from geologists, differing as it does so much from most rocks. Chemically, it consists of carbonate of lime, or a mixture of the metal calcium, the gas oxygen, and the same substance which forms charcoal, —carbon. It is considered to be one of the newest or most recently-deposited rocks,— older than the tertiary and drift, of which we spoke in the last chapter, but much later than the coal-formation. To speak very accurately, chalk, with its attendant strata, occupies a space between the clay, sand and gravel of the tertiary strata and the series of strata called oolites. It abounds with fossil organic remains of marine plants and animals, as well as the flints already noticed, in regular lines. Iron pyrites seem to be its only metal. It has a whole world of fossil animals of its own. Considered as a rock, it has been deposited in lakes, or small seas, or estuaries running up from the ocean, which have been thus filled up and are now lifted above the sea-level and form dry land. Such is the great chalk-basin of Northern France and Southern England, cut in two by the Straits of Dover. Here the chalk is best known and has been most closely studied. But it occurs in Spain and other parts of the south and east of Europe, in Sweden, Poland and Russia, in the island of Crete, where it got its ancient Latin name of Creta, and in Mount Lebanon in Palestine. In South America there is a quantity of fine white marl in some respects resembling the lower chalk-formation, by which phrase is meant the strata or beds of material which lie lowest, and are generally harder and more compact than the upper portion. It has also been found in the western parts of the United States. In England, where it is cut through by the Channel, its long white cliffs are supposed to have suggested to the Romans the name which they gave that island,—Albion, from *albus*, white; and it is said that in the ancient religious books of the Hindoos an island is mentioned as the *white island*, the island of the blessed." Some have thought that the same island is meant.

In common language, chalk is called an earth, and its origin for a long time puzzled inquirers; but the microscope has led to the interesting discovery that it consists for the most part of the decomposed shells of multitudes of insects, so small as to be invisible to the naked eye. More than ten millions of perfect forms have been observed in a single pound of chalk, besides innumerable fragments.

Edward remarked that that seemed almost like the product of the coral-workers. Mr. Goodman explained that chalk is made up chiefly of minute separate shells, while coral is the secretion of continuous stony matter for the habitations of the insects. Chemically, the particles of chalk and coral are differently combined. The shells of nearly four hundred different varieties of insects now living have been already distinguished in the pure white chalk which abounds in England, many of which are identical with those observed in the coral shores of the Red Sea. In chalk-marl and coarse chalk, numbers of these shells are quite perfect, and can be separated, by soaking the chalk in water, sufficiently to show them under a powerful microscope; but the finer the chalk is the more are the shells broken and decomposed, till, in the best close writing-chalk, comparatively few are whole.

When chalk is put into water, it seems at first to melt and make the water milky, and some portion of the most dusty, decayed mass does no doubt combine with the water; but it generally settles as a sediment; and by brushing a piece of chalk under water, Professor Ehrenberg easily secured many specimens both of the bryozoa, or moss animals, and the polythalmia, or many-celled infusoria, which he found still living in the waters of Cuxhaven.

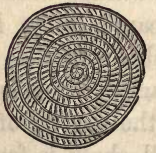
Some chalk looks so regularly grained that, without minute investigation, we should almost fancy it was crystallized; and perhaps it is nearly so: at least, the decomposed particles of shell are ranged in regular order and even-looking laminæ, though not quite so thoroughly united as they would have been if they had been crystallized in the manner of glass or rock-salt. It is rather curious that the chalk-beds of the south of Europe exhibit more well-preserved chalk animalcula and less of the crystallized-looking laminæ or grains, while in the north and east of Europe the chalk has more laminæ and fewer perfect remains. There is a remarkable difference also in the presence or absence of flints in chalk. In the south of Europe they are quite absent, and instead there are beds of marl composed entirely of the siliceous or flinty shells of infusoria.

It seems surprising to think of such pretty white chalk cliffs being made of old shells; but yet it may be noticed that shells powder into a very white, chalky sort of dust; and some people content themselves with the thought that this is because they are partly made of chalk. Chalk, however, properly so called, seems to have been the result of some animal process during the little creature's lifetime, or the action of carbonic acid derived from the atmosphere; and it certainly may be called "the dust of death," as truly as the black animal mould discovered elsewhere with fossil remains of larger size. The varieties of chalk seem also in some measure to depend on the sort of animalcula which most predominated.

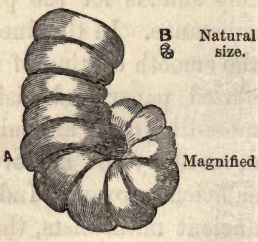
There seems no reason to doubt that chalk is still forming, as multitudes of the little creatures are perpetually dying, and leaving their tiny shields for the production of this white substance. In the finest whiting, and even on the smooth coating of white-washed walls and glazed paper and visiting-cards, these little moss-like coral animalcula-shells may be discovered by the aid of a magnifying-glass of sufficient power. Indeed, the saying of the ancient naturalists, that "all chalk is formed by worms," which for a long season was condemned as absurd, is far more correct than most of the theories which were substituted for it. How they came to that conclusion is wonderful;—as we have not learned that they possessed any thing like our modern and convenient microscopes. They either must have had very good eyes and used them diligently, or possibly they had contrived magnifiers of some description,—though no specimen or record of them has descended to us.

"We have several varieties of coral, father," said Alice, spreading her necklace and bracelets on the table and opening a drawer of elegant little specimens. "Do you mean to say that it consists of the same materials as this smooth, white chalk?"

Mr. Goodman replied that chalk and white coral can be calcined into lime, so nearly alike that we could not easily detect any difference, both being nearly pure carbonate of lime. Chalk abounds more in the temperate and northern regions, while coral is rarely formed except in tropical climates. Chalk seems a deposit left by waters receding or drying up; while coral is never produced

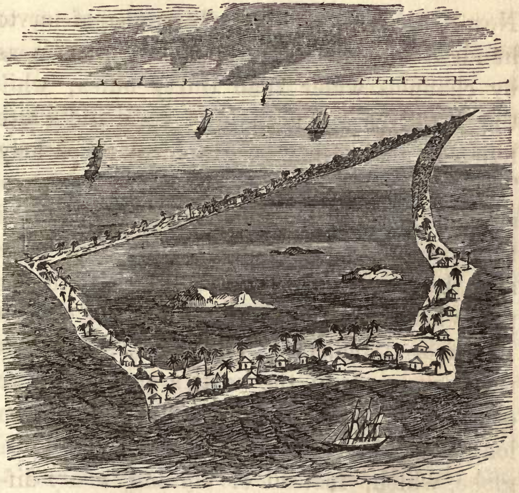


Section of Nummulite, Pyrenees.



Spiralina, Paris Chalk.

except under water, the insect invariably stopping his labours when reaching the surface. By degrees they have formed—in the Pacific Ocean especially—vast barriers and reefs, from fifty to one hundred feet thick, and extending from a few miles in some spots to hundreds of leagues in others. Many of the South Sea Islands appear to have been originally formed of coral-rock, on which soil has gradually gathered and vegetation ad-



Coral Island in South Seas.

vanced, till they have been prepared for the sustenance and residence of human beings. Disappointment Islands and Duff's Group are connected by five hundred miles of coral-reef, over which the natives can travel from one to another. Between New Holland and New Guinea is a line of coral-reef seven hundred miles long, in no place interrupted by channels wider than thirty miles; while the Maldives are a chain of coral-islets four hundred and eighty geographical miles long. These are the summits of long ranges of sunken mountains, around the peaks of which the coral-animals began to build their reefs, and have continued to build, though the peaks have sunk beneath the level of the sea. Professor Dana, of New Haven, shows how the movements of the earth's crust have accomplished this result. And he points out long belts of surface on the Pacific side of the globe, which, instead of sinking, are rising into the air; and along these the coral-reefs have been carried up hundreds of feet upon the sides of the mountains which line the coast. Such, for instance, is the case with the eastern coast of New Holland, where the coral-reef is in some places four hundred feet above the level of the sea. This need not surprise us, when, by turning to other parts of the globe, we may see Greenland, for example, slowly sinking, and Sweden slowly rising from the ocean at the rate of one and a half or two feet in a century. The west coast of South America is also rising.

It is astonishing that insects should make such extensive works; but these industrious and persevering coral-insects appear to have existed from all ages: and when we remember that five hundred millions of the chalk-insects can find room to sport in a single drop of water, (according to Ehrenberg's statement,) and that each one can multiply to one hundred and seventy billions in four days only, the wonder seems somewhat less incomprehensible.

It is not known how long the coral-animals live and work, nor exactly at what rate the growth of the coral-reefs goes on: Many and very inconsistent estimates have been made, amounting to little more than conjectures; and, in fact, it depends on the kind of coral-animal of which the question is asked, for some grow faster than others. The increase of coral has not yet been much watched; but we can form some idea of its progress from the history of a ship sunk in the Gulf of Mexico during a heavy storm. It was laden with silver; and, thirty years afterwards, divers were employed to try and recover some of the treasure; but great difficulty was experienced in getting to the ship, from the quantity of coral which in that time had overgrown it. Sir Hans Sloane tells us that the ship's timber, the iron and money, were all concreted by the growth of a calcareous or limestone matter.

Wherever the bottom of the ocean is settling down and carrying out of sight the mountain-summits, there the coral-reefs are ranged in a circular manner, with a lagoon, or shallow lake, in the middle; and on the leeward side is a single opening, through which the tides set, or the extra water, which in high storms is dashed over the windward portion of the reef into the inner lake, is allowed to run out again. Along the reef runs a narrow grove of cocoanut or bread-fruit trees, on which the inhabitants, if any there be, subsist. And along the edge, just under the water; is an abundance of elegant varieties of coral, whose form and colours rival those of the most beautiful flowers; while among these stony groves float or dart a million brilliant fish, feeding upon the food they find upon the branching coral. This is of every shade of colour,—black, red, pink, green, white and yellow; and as to shape, some are branched like trees, others are pipe-like and fan-shaped. Masses of cabbage-leaf coral are as large as a gooseberry-bush. Some rise like tall grass or hang over like delicate feathers. Each variety of coral-insect builds a different-shaped house or body for itself; and one generation grows, like moss, upon the dead layer of the generation which preceded it. The most violent storms have no effect upon the living coral, which flourishes best upon the windward side, but only dash up on the reef the dead branches and huge masses, which are afterwards ground to powder and spread far over the bottom of the sea.

It is impossible to say how many varieties of coral-workers there are; for Ehrenberg, D'Arbigny and others are continually discovering more. Already, however, fifteen hundred varieties of foraminifers are known to science, seven hundred polythalmian or many-celled insects, and three hundred and eighty-six anthozoa, most of which still exist.

The bright-coloured and branched corals are used only for ornamental purposes, such as ladies' necklaces, bracelets, brooches, rings, &c.; and their value depends upon the size, shape, colour and solidity of the specimens. The red and black varieties are most highly esteemed. Some portions of Sicilian coral have realized eight or ten guineas the ounce, while other parts of the same mass have been sold for one shilling the pound. Coral is mentioned very anciently, being noticed in the book of Job as common, and in Ezek. xxvii. 16 as an article of trade with the ancient commercial city of Tyre. Large quantities are still brought from the shores of the Mediterranean and Red Seas, the Persian Gulf and the coast of Sumatra. In ancient times black coral was deemed a very efficacious divining-rod.

Coral-rock is often used for building-purposes in the South Sea Islands; and Mr. Williams, in his "Missionary Enterprises," describes the beautiful plaster, of delicate *bloom* colour, which he made from calcined coral, to adorn the walls of his chapel and school-house. Indeed, the Sphinx of Egypt, and some of the pyramids, are built chiefly of nummulitic limestone, consisting of small-chambered shells disposed in so flat a whorl as to resemble a piece of money, called in Latin *nummus*. These are cemented together by the chalky remains of thousands of smaller insects.

"Yes," said Edward's uncle; "I remember that in the Alps of Dauphiny, one day, I came to an old church in a village in the Val de Bourg d'Oysans, at least six thousand feet above the sea, which looked so worn and ancient that I climbed the cliff on which it stood, to examine its walls; and, to my astonishment, I found them all worm-eaten, as I thought at first, an inch or two in depth. But when I examined the stones more carefully I found that they were only weather-worn, so that the corals of which they were composed could all be seen and studied. In the lapse of centuries the storms had dissolved and carried out the softer mud between the branching coral. This gave the church its gray and venerable air."

Speaking of the nummulite fossils, continued Mr. Goodman, who had listened with pleasure to this interruption, a specimen of nummulitic limestone from the Crimea is precisely the same as one from Egypt, but becomes fragile and crumbling when exposed to the air.

None of these curious shells are now found as living animals, for the nummulites seem to be quite extinct: indeed, it is a curious fact that there is a much larger variety of *extinct* infusorial shells than now exist; and, from the known habits of their successors in the present day, they were a sort of scavengers in creation, eating up refuse vegetable matter, and were themselves the prey of larger insects; while their bony coverings were left, not only to form the rocks we now behold, but to furnish stone for building, powder for white-washing and plate-cleaning,—even the glasses out of which we drink, and the medicine we take for the cure of disease. Well may Ehrenberg assert "that though these microscopic organisms are inferior in energy to lions and elephants, yet their united influence is far more important than that of those animals."

Alice looked puzzled at this statement, and inquired how it could be made out that they furnish all these useful articles.

Mr. Goodman then told her that all limestone and all marbles are but chalk in another stage. The glass we drink out of and furnish our windows with, depends largely on flint sand for its transparency and pureness. Chalk finely ground is a most useful medicine for some diseases,—though, like most other medicines, injurious if taken in excess. Chalk is sometimes prescribed by medical men for various ailments: camphorated chalk is used for tooth-powder.

It is very useful as an absorbent and corrective of acids, but, of course, needs professional skill in its application. Some drawing-chalks are made of this pure white material,—nearly all the white, gray and black crayons; but the red, and other colours, are generally prepared from varieties of clay and ochre and coloured with metallic oxides. Chalk calcined, or burned to powder, is used in putty and various cements, and also for manuring land—as it greatly promotes the growth of the short rich grass which improves sheep—for pasturing fine Southdown mutton.

The calcined MAGNESIA of the apothecary looks something like chalk, and is an earth of similar nature, deriving its name from the province of Asia Minor where it was first used. It is now found pure in Piedmont, Moravia, the United States and the East Indies; but it mingles in the composition of many mineral substances, making them feel soft and soapy to the touch. The magnesia of the druggist is generally prepared by calcining the magnesian limestone, which drives off the water and carbonic acid, or from the most bitter sea-water or magnesian spring waters.

There is a particular formation, below the chalk and above the coal, to which the English geologists who first studied the rocks gave the name of the Magnesian Limestone; and this name is still retained. In this limestone are found shells and corals in abundance, and also the scales and teeth and bones of ancient fish, such as are no longer found in the seas by fishermen. But there are many others which deserve it as well. The Missouri and Kentucky geologists called the oldest and lowest limestones of all Magnesian Limestones; for so they are, and the springs which flow from them are like medicine, and injure both man and beast. It is from drinking this water where it stands in pools and becomes strong that the "milk-sickness" of the West originates. Sometimes soda is more common in the limestone than magnesia; such is the case with the mineral water which rises in the deep Artesian well of Louisville, Kentucky. When the carbonate of lime and the carbonate of magnesia are in exactly equal proportions, the rock is called a dolomite. Many of the limestone rocks of Canada are dolomites; and so are many of the rocks of the Alps. There is one entire mountain, six thousand feet high, rising in the Alps like a great tower with straight sides, all dolomite; and travellers come from afar to see it, on account of its grandeur.

The metal magnesium is the basis of magnesia, which mingles in the composition of several minerals. Meerschaum, or foam of the sea, is an earthy carbonate of magnesia, extremely light, of a yellowish-gray colour. When first dug, it is soft and greasy, and lathers, like soap: the Tartars use it for washing clothes, and the Turks for making smoking-pipes.

MARL belongs to these chalky earths, and seems to be still undergoing the process of formation. It is a mixture of chalk, or carbonate of lime, and silica, alumina, with sometimes a little bitumen and oxide of iron. It is termed shell-marl, or clay-marl, according to the material chiefly predominating, and, being always found in valleys, which were formerly lakes, or on the shores of lakes now existing, the idea is confirmed that it is derived partly from the sediment of lime-springs, and partly from the decomposition of the shells or secretions of the fresh-water shell-insects inhabiting the waters. Marl is dug from open pits, and much used for dressing land. It sometimes becomes solidified by nature's chemistry into rock-marl. The shell sand of the Cornish beach is so valued as a manure that five or six millions of cubic feet are annually conveyed from the coast and spread over the inland fields. When left undisturbed on the shore, it gradually consolidates into beds of considerable thickness. I have already described to you the shell-marl and greensand-marl of the Atlantic coast, which constitute so valuable a manure.

Various proportions of carbonate of lime, with small mixtures of other materials, produce beautiful minerals,—such as *arragonite*, consisting of a mass of glossy, silky-looking fibres of mixed colours,—green, pearl, gray, violet and blue. It is sometimes termed *flos ferri*, or iron silk, and is somewhat like asbestos in appearance; but asbestos consists of very little lime and alumina, with a great deal of silex and magnesia, and a small quantity of oxide of iron. It is so pliable that its fibres can be separated and woven into cloth. It does not consume in fire, and was therefore much used by the ancients for wicks to their oil-lamps, while the bodies of the dead were frequently wrapped in its cloth to preserve the ashes separate when burned, as was customary among many nations. There are various kinds of asbestos, bearing the names of amianthus, mountain cork, and mountain leather, mountain paper, or mountain wood, as its texture most nearly resembles these substances. The cloth of asbestos is purified by burning; but it loses weight, and becomes less flexible. Under a very strong heat the fibres appear to melt; but, instead of running together in a mass like metals, they moulder and fall down, and are blown away by any slight current of air. Fine specimens of asbestos are found in the Highlands of New York; and the fibres are worth, when long and silky, four dollars a pound. They are used now in small bundles to place in the tubes of camphene and other explosive-oil lamps, because the flame will never travel back between them. They are also used by dentists, who melt their delicate ends with a blow-pipe and thus obtain a remarkable kind of solder. They have been woven into cloth and made up into dresses, in which men have walked through fire and not been burned, or into gloves, with which red-hot iron has been handled safely. The coarser kinds are used in stuffing the sides of fire-proof safes. It is a remarkable mineral; but many of the earths are as remarkable for beauty as this is for its utility. Gems are mostly crystallized earths.

When Mr. Goodman began to talk of earths, Edward pointed to the black garden MOULD, and asked what it was. His father told him that it is chiefly the result of decayed vegetables, with a mixture of animal matter. The coral-rocks do not exhibit earth enough to be fruitful till several seasons of vegetable growth have lived and died upon them, while the gases which these vegetables imbibe from the atmosphere not only combine with the surface of the rock, changing its composition and making it crumble, but their decay generates new gas; and the fluids of sea and land animals add another source of fertility, while turning into that material of which they were first created.

In the limestone cave of Kuhloh, in Germany, more than five hundred cubic feet of black animal dust, impressively denominated "the dust of death," was found, resulting entirely from the decomposition of bears who inhabited such caves in ancient days; and in Portland Island, Lulworth Cave and other places, there are layers of "black dirt," as the quarrymen call it,—an ancient vegetable soil, of dark brown or black colour, from twelve to eighteen inches thick, evidently formed from the decay of leaves, since earthy lignite, silicified trunks of trees, and other remains of plants, abound in it. These facts wonderfully illustrate the words of Scripture, "Dust thou art, and unto dust shalt thou return;" and also the New Testament declaration, "This mortal must put on immortality." Those who watch the ceaseless round of decay and reproduction which perpetually renews the face of our earth, rendering it beautiful to the eye and a useful dwelling-place for men, must find their belief in the promised resurrection greatly confirmed; for He who can produce such brilliant gems and such fragrant flowers from unsightly soil can assuredly change our vile bodies, that they may be fashioned like unto the glorious body of our Lord Jesus Christ; and those who love and trust him will not only see him, but be like him in the world to come.

CHAPTER VIII.

LIME—MARBLE—GRANITE.

THE old town-hall could be propped up no longer. Its picturesque gables nodded alarmingly over the pathway, and its worm-eaten timbers were perpetually giving way, so that their original carved work could scarcely be traced. It was, therefore, condemned to destruction, and the artists set to work to delineate its venerable appearance, while the architects devised plans for a new building, which should be the pride of the county. Mr. Goodman was one of the building-committee; and Edward, whose antiquarian reverence for the old hall did not abate his boyish delight in the progress of the new one, was continually on the spot, equally interested with all that the old masonry revealed by the breaking down of the old plaster and partitions, and the deposit of the new materials for the structure now contemplated.

Sometimes he was permitted to stay in the committee-room; and his favourite grotto-work much increased his interest in the discussions upon the comparative merits of brick and stone, granite and marble, specimens of which passed in review, and, when done with, were not unfrequently bestowed upon him and other young people who took part in making "the friendship-grotto."

The new town-hall was a handsome affair. Day by day it rose higher and higher. The walls were of gray granite, the floors and staircases of white freestone, while the broad fireplaces of the principal apartments were of Italian marble, some red and some black, but so highly polished as to exhibit every tiny marking peculiar to that substance. Edward and Alice admired this very much, and soon discovered the shells with which it was studded. They then examined all the varieties of marble in the grotto, and perceived many containing similar remains, especially when they used their magnifying-glass to any wetted smooth surface; and they sought the first opportunity of asking their father if the marble was made of any kind of chalk. Mr. Goodman told them that all marble is limestone, and, as chalk is one variety, of course they consist of similar materials, though in different conditions. LIME, and especially the carbonate of lime, of which chalk and marble are the purest specimens, abounds so largely in the rocks that it is estimated to form one-seventh of the crust of our globe.

He further stated that the great mass of all known rocks seems to consist of different combinations of eight or nine simple materials; and these are called quartz, felspar, mica, hornblende, the carbonates of lime, magnesia, soda, potash and oxide of iron.

The substance termed MARBLE abounds in all great ranges of the primary or earliest-formed rocks of Europe, in the north of Africa, and in the United States; while we know from the Bible that marbles of various colours were early used as building-materials, both in Syria and Persia. David delivered to Solomon "marble stones in abundance" for the temple; and the palace of Ahasuerus was paved with "red, blue, white and black marble or alabaster." (Esther i. 6.) The sculptured slabs of Nineveh and stately white columns of Persepolis attest its use among the wealthy nations who flourished in ages long gone by. Quarries of marble have been lately discovered undermining Jerusalem, with blocks hewn and partly squared, as if the workmen had but lately left them. The most compact and highly crystallized is esteemed the best. Some is of a dazzling white colour and close grain, resembling fine loaf-sugar, and hence is called by some writers saccharine marble. It is valued for statuary. Such are the Parian and Carrara marbles. These will take so high a polish as to appear almost translucent. From Carrara not less than half a million's worth of white marble is now annually exported. The quarries are very accessible, and the rock so free from flaw that large blocks, of two hundred cubic feet, can be detached by means of very simple machinery. Marbles in great variety were used by ancient sculptors, as may be seen in the British Museum; but their localities are not all known now. Very fine white statuary marbles have been of late discovered in the State of Vermont; and three sides of the Girard College at Philadelphia are built of white Vermont marble, because the white marbles of the Schuylkill quarries, near Philadelphia, furnish only a limited supply. Similar white marble occurs all along the line of the Blue Ridge region, as far as South Carolina.

Alice here inquired the meaning of the word marble,—because she had noticed that such very different-looking substances were called by that name.

Her father replied that it is of the same origin as the French word *marbre*, the Latin *marmor*, and the Greek *marmaros*, shining or glittering. All marbles effervesce with acid, and consequently are injured by acid applications; and all will burn into ordinary lime. They are variously marked, according to the different substances mingling with them, or their different degrees of compactness, and are differently grouped by scientific persons. Sculptors and architects distinguish them into about eight sorts: namely,—one-coloured,—pure black or pure white; variegated,—marked with irregular spots and veins; madrepore,—when studded with round encrinitic or coral markings; shell,—when only a few shells are interspersed through the mass; lumachelli, or fire marble,—entirely composed of shells, with veins of flame-coloured crystal flashing like fire as the table is moved; cipolin,—containing veins of greenish talc;

Breccia marbles,—formed of angular fragments of various composition and colour; and pudding-stone marble,—when the fragments are round instead of angular.

This is a stone called *verde antique*, which is a curious, and rather pretty, mixture of *white* marble and *green* serpentine. The Welsh Mona marble is very similar. Fine dark-gray and purple marbles are found in Ireland, and known under the names of the places whence they are quarried. A fine black marble, with a white shell, was so admired by the Roman consul Lucullus that he gave it the name of *lucullite*. The same sort is now found in Derbyshire, Kilkenny, Cork and Galway, and is sometimes called Nero antico by the Italians, who are fond of distinguishing every variety by some new and peculiar name, and sometimes give two or three different names to the same stone,—a practice that is very puzzling to youthful collectors and inexperienced artists. Verde antique is also found in Vermont.

The Florentine ruin marble is a very compact limestone, and, seen at a little distance, resembles drawings done in bistre, or wood-soot. The blue Vesuvius marble is generally found in loose masses among blocks of stone ejected from the volcano, though not having, apparently, been melted or heated by the subterranean fire. This was used for the sky in ancient mosaic-work.

Mr. Goodman then turned to some specimens of Bath stone and Portland stone from England, remarking that these and other oolites, of which they are a part, extend, with little interruption, across the island. This class of stone is formed of minute, round concretions of lime, hence called roe-stone oolite, or fishing-rock. It is much used by architects; but it is very porous, and therefore easily affected by the weather, which makes it moulder away. Oolites of a much older age occur in the United States, but are very scarce.

The pea-stone is very similar, but the grains are larger, and composed of concentric layers, enclosing a bubble of air, a grain of sand, or some fragment of mineral matter: it abounds in Bohemia. A similar substance, called tufaceous limestone, is found encrusting various substances, such as leaves, shells, bones, &c. In the British Museum is a human skull covered with lime-crystals deposited by the river

Tiber. Indeed, Rome itself is built very much of travertine, a stone composed in this way, and the formation of which is still in progress.

There are numerous delicate white veins and crusts sometimes seen inside of limestone caves, which are called agaric mineral, or rock-milk. It is produced by the continual action of water upon the surface of limestone. When water drops through the roof of a cave, long pendants, like icicles, are gradually formed, hanging in tubes or branches, and sometimes in sheets resembling drapery: these are called stalactites. The same waters sometimes drop on to the floor, and, as they run off, leave a mass of hardened carbonate of lime in irregular shapes: those are stalagmites, and are sometimes so finely crystallized or compacted as to merit the name of alabaster. The Oriental alabaster, however, has in it a small admixture of gypsum, or sulphate of lime. This is often used for scent-boxes; and some think that the alabaster box filled with precious ointment, mentioned in the Scripture, was made of this delicate material.

The Grotto of Antiparos, in the Archipelago, is described as filled with petrifactions of all colours, so singularly disposed as to resemble trees, flowers, brooks and animals all turned to stone. The floor is rugged with brilliant lime crystals, of red, blue, green and yellow; while stalactites of white marble, fallen from the roof, mingle among them. One side of the passage to this remarkable cave is a sloping wall formed of a single mass of purple marble, studded with rock-crystals, looking like a row of amethysts. Some of the stalactites are five-and-twenty feet long, of dazzling whiteness, and yet so transparent that, when illuminated by torch-light, the low, narrow alley by which it is entered glitters as if it were really the fabled valley of diamonds. The Castleton Cave, and crystallized caverns in the Peak of Derbyshire, owe their beauties to similar stalactites and crystals. The celebrated Austrian caves of Adelsberg and Magdalena have wonderful sheets of stalactite, behind which the guides hold their torches, and make them appear like transparent-white glittering curtains. A river flows through one of these caves for several miles; and in it are many of those whitish, slimy, half-lizard half-fish like animals without eyes and furnished with both lungs and gills, which naturalists have called the proteus anguinis.

Weir's Cave, in Virginia, is a miracle of beauty. In one of its rooms, called the music-hall, parallel sheets of alabaster hang from the roof, and, when struck with a mallet, give out various organ-tones of a grandeur in harmony with the mysterious darkness of the scene. In another room the limestone drippings have formed a gigantic statue of Washington.

But of all the caves in the world known to man, the Mammoth Cave of Kentucky excels in size and variety of admirable sights. Its profound abysses, where lakes and rivers lie,—its long galleries and lofty domes,—its monstrous columns covered with crystals,—its roof of stars, as it seems to the eye when lit by the torches of travellers,—fill the mind of the beholder with wonder and awe.

Edward pointed upwards, where a few humble specimens were here and there stuck on the roof of the grotto; and his father continued to state that in one of the English coal-mines, it is said, there is a constant formation of limestone, caused by the trickling of water through the rocks. This stone would be always white, like white marble, were it not that men are working in the mine, and as the black dust rises from the coal it mixes with the soft lime and thus tinges it black. During the night, however, when no coal-dust rises, the stone is white; the next day, while the miners work, a black layer is deposited; and so on alternate layers of black and white are formed during the week, till Sunday comes. Then, as the miners do not work on the Sabbath, so much larger a layer of white stone occurs, that they call it "the Sunday stone," and can thus note their Sabbath observance marked for them on this stone.

At West Stockbridge, Massachusetts, a calcareous breccia was formed in the short period of seventeen years, by the chips thrown off in hewing marble being cemented together by the lime sediment from a stream which flowed over them, till the breccia thus formed became nearly as solid as the original limestone. Such incidents as this afford interesting evidence of some of the modes by which God works in nature. At Clermont, in France, a mineral spring has dropped its limestone for many centuries, so as to form a bridge of rock, which it has pushed across a stream and is still forming on the opposite bank. Close by is a water-wheel, in a shed furnished with shelves, on which are placed baskets, birds, coins and other objects, which are all coated with the spray and turned at last into stone.

The pretty satin-spar necklaces which you buy in the shops are nothing but fibrous limestone, found chiefly in Derbyshire, England, where the rarest and most beautiful lime crystals are found,—though various sorts are met with in every part of the world. Some of these crystals are very pretty, and appear in six-sided and three-sided prisms, and also as pyramids. Indeed, calcareous spar, or lime crystals, occur in no less than six hundred different forms, and vary in colour,—gray, blue, yellow, green, red, white and brown. The transparent crystals reflect double.

Gypsum, composed of sulphate of lime, is known as alabaster, and, when reduced to powder by heat, forms plaster of Paris,—so called from the quarries near Paris, where the mineral abounds. It is found principally above the chalk-formation. Calcined, powdered and mixed with water, it easily runs into moulds for images, and ornamental work for buildings. It is also used for stereotype and pottery moulds, and for models and casts of various kinds. Mixed with quicklime, gypsum makes an excellent mortar, and, simply ground and powdered, is considered a fertilizing manure for land. Many of the Derbyshire and Staffordshire gypsum-quarries yield specimens compact enough for the turning-lathe, which are made into jars, vases, and chimney-ornaments, almost rivalling in beauty the specimens of alabaster brought from Volterra, in Tuscany. A very large trade in alabaster statues, boxes, pedestals for time-pieces, &c., is carried on in Italy, where the chisel is used as well as the lathe; but all alabaster articles require to be kept closely under glass shades, as exposure to the air quickly destroys both their colour and translucency. I have already told you how the American gypsum is found in Nova Scotia, in Central New York and in Southern Virginia. But there are vast fields of gypsum also in Western Arkansas and among the Rocky Mountains.

The pavement in the streets of Plymouth in England look veined and polished, like marble, when it rains: being made of the common marble abounding in Devonshire, the rain displays its markings as well as polishing would. Limestone, with admixtures of magnesia, silica, sulphur and several other substances, produces many varieties of rock and stone. Some of these, as the stinkstone, or swinestone, emit a peculiar fetid smell when rubbed; others give not only a phosphorescent odour, but light tinged with different colours. Magnesian limestone—sometimes called dolomite, after Dolomieu, a French geologist—is one of the hardest and most durable varieties. The beautiful white sort found in the isle of Tenedos was much used by ancient sculptors; and modern architects still esteem it for building. Thin long slabs of this dolomite, and even of common granulated limestone, may be rendered flexible by exposure to heat for a few hours. Some tables made of this in the Borghese Palace at Rome excited much attention among the curious. A similar species exists near Tynemouth Castle. It is cream-coloured, and is easily cut with a knife. It is extremely porous, and loses its flexibility when moderately dry, —though when either very wet or very dry it readily bends. All marble is elastic; and a slab will quiver when shaken.

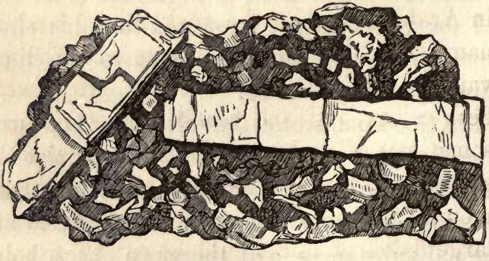
Serpentine is another pretty, green mixture of lime, magnesia, alum, iron, &c., some varieties of which are magnetic. The smooth, compact stones used by lithographers for their drawing or writing plates are often made of lias, or magnesian limestone, from Bavaria. Lime is also much used in mortar, and for stucco. Veins of lead, zinc and silver are frequent in limestone rocks; among the bunches of lime crystals, cubes of lead and copper are often seen, in pretty contrast with the pure white crystals.

Edward asked how, if limestone is so useful for pavement, it happened that his shoes were so spoiled when he went to the lime-kilns some days before.

Mr. Goodman stated that all calcined or burnt lime is called quicklime, and when deprived of carbonic acid is exceedingly caustic, quickly causing decomposition, both of vegetable and animal substances, and therefore shoes, being made of leather, would be speedily destroyed by it. Lime is used for this very purpose by tanners for making wash-leather. When exposed to the air, lime quickly imbibes carbonic acid from the atmosphere, and is then a useful addition as manure for corn and grass lands.

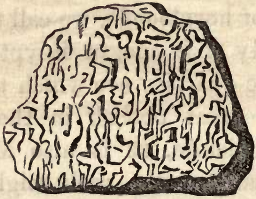
In ordinary language, lime is termed an *earth;* but chemically it is the *oxide,* or *rust,* of the metal *calcium.* This metal, however, is never found in its native state, and, when procured in small quantities by the chemist, it quickly becomes an oxide again. When water is thrown on lime, it is observable how quickly it is absorbed, while much heat and vapour are perceived. It is obvious enough when the workmen slack lime, as they turn it.

Edward took up one or two specimens of GRANITE, asking if they were made of lime.



PORPHYRITIC GRANITE.

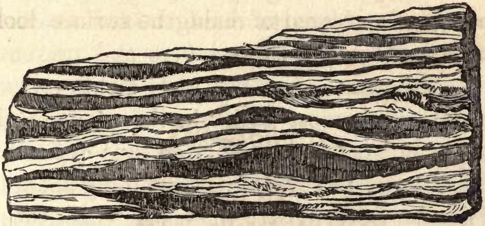
No, said his father. Granite is a rock compounded of quartz, felspar and mica, with sometimes other substances, among which may be lime,—but very seldom. Stonecutters speak of forty-two kinds of granite. When the crystals of felspar are very large and imbedded in a cement, the rock is called *porphyry*. When, instead of the rock being solid, it is made up of thin layers, and the flakes of mica seem to lie in one direction, and the quartz is not well crystallized, we call the rock *gneiss*. When instead of shining specks or flakes of mica we have black specks or crystals of hornblende, we call it *sienite*,—from the city of Syene, in Egypt, where the great temple-quarries are which the ancients used. The great obelisk in the centre of Paris is of sienite, as is also Mount Sinai in Arabia: so that the rock might bear the name of *sinaite* as well as *sienite*. The prevailing colours of granite are gray, white, flesh-colour, red and black. It is composed sometimes of such coarse materials that the separate crystals are a foot or more in diameter. In some lumps of American granite large flakes of mica could be cut off from the shining parts. The mica of the Highlands of New York comes out of the rock sometimes in plates two feet square. In Russia such plates are used for window-glass. In other kinds of granite the grains are so fine as to be scarcely distinguishable by the naked eye; and between the coarsest and the finest there is great variety. The finer kinds are the most useful, and the coarser most interesting for the various minerals observable in them. One sort is called graphic granite, because the crystals of quartz make the surface look as if covered with letters.



GRAPHIC GRANITE.

The gray Aberdeen granite is now valued for building and pedestals, as it is susceptible of a high polish. That of Peterhead is reddened by oxide of iron in the felspar crystals. The Grampian Hills in Scotland, the Cumberland and Cornish Hills in England, the Wicklow Mountain in Ireland, the Alps in Switzerland, the Pyrenees in Spain, the Dofrefield in Norway, the Ural Mountains in Russia, the Abyssinian and other African ranges, and the

Andes in South America, are all composed of rocks more or less granitic. Indeed, as Humboldt remarks, "when we pass to another hemisphere, we see new forms of plants and animals, and even new constellations in the heavens; but in the rocks we still recognise our old acquaintances,—the same granite, the same gneiss, the same quartz, and the rest."



GNEISS.

The first railroad in the United States was made to carry the celebrated Quincy granite to Boston; and in the neighbourhood of these quarries has been found recently that extraordinary fossil trilobite called the Paradoxides. Similar granite-quarries are wrought on Cape Ann near Gloucester. New Hampshire is often called the Granite State. Great dikes of granite rise through all the rocks of the Lawrentian Mountains in Eastern Canada.

Gneiss, as I have said, continued Mr. Goodman,—for no one seemed disposed to interrupt him,—gneiss, of which I see more than one specimen built into your grotto, is a rock composed of the same materials as granite, but differently arranged. It has been called stratified granite, because the felspar, mica and quartz, instead of being mixed together, occur in thin, irregular layers and present a pretty surface of dark and light stripes. Gneiss splits most easily in the plane of the darker layers; and the surface thus exposed is almost entirely covered with shining spangles of mica. Occasionally the layers constituting gneiss, instead of occurring in thin laminæ, are divided into thick beds. Where veins of granite and gneiss intersect each other, the gneiss appears to have a larger quantity of felspar and to be of redder colour than usual.

This shining mica, which peels off so easily into flakes, is one of the many compounds of silica and alumina with oxide of iron, and potash. It is transparent, and sometimes is found in crystals more than a foot square, and can then be split into thin plates for windows and lanterns. It will bear heat and vibration better than glass, and is therefore well adapted for ship-lights, (when glass would be shattered by the report of cannon,) and also for anthracite-stove doors. The largest sheets of mica are brought from Siberia, and termed Siberian glass.

Talc is a softer, yet less elastic, sort of mica, owing its peculiarity to the presence of magnesia. It is used in making porcelain paste and in polishing alabaster, and is sometimes mixed with rouge for the toilet, to soften the skin. Carpenters and tailors use it as a marking-material. There are said to be ten sorts of mica, each bearing a different name. The baldstein or figure-stone of China is soft, and easily cut into the grotesque figures brought from that country. The pearly gray or red lapidolite of Scotland is cut into beautiful snuff-boxes. The green earth of Verona forms the mountain-green of artists in water-colours; and steatite, or soapstone, is useful for removing grease from silk and woollen stuffs. Many savages—especially those on the banks of the Orinoco—eat great quantities of steatite. It does not really contain nourishment; but probably it removes the sense of emptiness, which is so oppressive.

Granite and porphyritic rocks are solid, not stratified, and seem to owe their mixture in a great measure to heat, and are therefore termed igneous rocks. Many kinds of porphyry seem to have been vitrified, or turned into glass by some natural process, while the admixture composing granite appears to have been nearly in the condition of boiling mud, yet not so completely fused as lava usually is. Chalk has actually been converted into crystallized marble by heating it powerfully in a closed gun-barrel.

Granite rocks look very beautiful, and give one an idea of strength and firmness. So obvious and striking are these and other characteristics of rocks, that it is not surprising that they are frequently used in the Scriptures to illustrate the character and attributes of God. Indeed, the Scriptures having been written in lands abounding with rocks, the minds of the inspired penmen gathered many figurative illustrations of divine truth from the scenery around them, whether wandering in the deserts of Arabia, peacefully tilling the Land of Promise, or wearing away the seventy years' captivity in Babylon. Sometimes the eternity of Jehovah is suggested by the "Rock of ages;" sometimes his protecting power, "Be thou my strong rock," (Ps. xxxi. 2;) a refuge in danger, "Lead me to the rock that is higher than I," (Ps. lxi. 2;) a place of refreshment and safety, "As the shadow of a great rock in a weary land." (Isa. xxxii. 2.) And this same substance is typical, in man, of his hardened heart, insensible to all the spiritual tillage of prophets and apostles, till, under the Holy Spirit's influence, the word of God—like as a fire, or "like a hammer that breaketh the rock in pieces," (Jer. xxiii. 29)—leads the broken and contrite sinner by faith to drink living water from "that spiritual rock, which is Christ."

The rocks, too, that rent at the time of his atoning death on the cross, may remind us that the barriers between God and the sinner were then removed, and that henceforth we may sing, with joyful confidence,—

"Rock of ages, cleft for me,
Let me hide myself in thee."

CHAPTER IX.

VOLCANIC PRODUCTIONS.

Mr. Goodman read from a New York newspaper, "The eruption of Vesuvius may now be said to have terminated, after three weeks' activity, during which a prodigious quantity of lava has been ejected."

Edward remarked that Mr. T—— sent a box of different stones for the grotto, some of which, he said in his letter, came from Naples, and all were volcanic productions: they were called obsidian, pumice, basalt, amygdaloid, trap, trachyte, sulphur, and some other names on the labels, besides several kinds of lava.

Mr. Goodman replied that lava is a general term for all the molten rock or fluid mass ejected from any volcano during an eruption; but it is composed of a great many different materials, which naturally assume various appearances in cooling, and from the action of the atmosphere. Most of them can be separated by chemical means. Felspar and augite are the chief substances; but so many others are frequently mingled, that in the productions of Vesuvius alone not less than one hundred different specimens of minerals have been detected: they, however, form but a small proportion of the whole mass of lava.

While pouring fresh from the crater of volcanoes, competent observers describe lava as much resembling a river of red-hot metal issuing from an immense furnace. No real flame rises from lava alone,—though trees, half-lighted cinders, and other matters, falling into it, take fire and blaze up. In the daytime its course is marked by a thick white smoke, and at night this reflects a light from the red-hot lava below. In the crater of the volcano of Kirauea, in Hawaii, one of the Sandwich Islands, there was seen, in 1840, a lake of red-hot lava, two miles in circumference, tossing its fiery surge and flaming billows in terrific forms. This was its "quiet mood," when only a half-smothered, gurgling sound—the stifled mutterings of a boiling fluid—was heard; but occasionally reports like those of musketry resounded. Jets of lava rose ten or twelve yards, or the separate pools in different parts of the crater boiled over, and glowing streams poured out for a while, and then settled down again to the usual "grum murmur."

This being the "quiet mood" of the lava, we may well imagine what its noisy moods must be. They differ, however, at different times. Some eruptions of lava are attended with noise, as if from a continued discharge of artillery or thunder, and flashes of electricity resembling lightning are seen illuminating the clouds and vapours; and when poured in cataracts of fire from cliffs into the sea, as is frequent in Hawaii, Iceland and elsewhere, frightful hissings and detonations mark its plunge into the waters,—where it kills the fish for twenty miles round, and actually cooks them by the heat imparted to the waves.

We cannot at all guess the quantity of lava there may be in any volcanic mountains; but there is reason to think that it comes from an immense depth below the surface of the earth; as from Etna alone the quantity ejected in 1660 was supposed by some to be twenty times greater than the whole mass of the mountain; and in 1669 it covered eighty-four square miles, destroying seventy-seven thousand persons. The matter then thrown out, if extended in a thin stream, would have reached four times round the earth.

On first issuing from the crater, lava often flows very quickly; for Dr. Judd, who visited the volcano, on one occasion was standing close by one of the molten pools of Kirauea, when it suddenly overflowed, and he had barely time to escape from a stream of lava, which not only covered the spot on which he had been standing, but spread over a space one mile wide and half a mile long. Two hundred million cubic feet of lava were ejected on that occasion. Its pace soon slackens, from the stiffening of the crust, or outside portion of the mass. After flowing a hundred yards or so, a scum forms on its surface, bearing cinders, ashes, and even stones of considerable size. Sometimes the lava finds a passage under ground for some distance, and reappears, cleared of this scum. But it soon gathers upon it again, and, as the lava cools and loses its liquid appearance, it rather resembles a moving mass of red-hot coals, heaped up, like a wall, from ten or twelve feet high to two hundred and more. The cinders rolling from above keep up a continual noise, like that of a shingle beach when moved by the action of the waves. The scum soon cools into a thick crust, which can be crossed by foot-passengers,—though at the risk of its burning their feet, or of breaking through it: so that it should not be attempted except on extreme emergencies, such as being unexpectedly enclosed by two streams of lava.

Boiling lava is much hotter than boiling water, though how much is not ascertained, as it is impossible to get near enough to plunge any thermometer into the hottest portion of it,—even if such an instrument would bear its heat. In 1822, lava, some days after its eruption, was found greatly to exceed boiling-water-heat when a thermometer was held three feet distant from it. Glass and silver melt on being placed in fluid lava; lead becomes fluid in four minutes; while double that time is requisite to melt a mass of it upon red-hot iron. When bell-metal was submitted to the heat of lava, in 1794, the zinc was separated, but the copper remained untouched. Lava is a bad conductor of heat: so that, while the outer surface cools, the inner portion retains its heat for a long period.

Hence copper coins are enveloped in still soft lava by the guides of Vesuvius, for the amusement of travellers; sticks thrust below crusts that have been cool enough to walk upon for years, readily take fire; and boiling water issues from the souffrières or craters of volcanoes that have been extinct beyond the memory of man. I boiled eggs in many of these fountains in the souffrière of Montserrat in 1856, which no one then living in the island had ever known in active eruption.

It is quite impossible to fix any date to the beginning of volcanic action on our globe. The composition and condition of the oldest rocks leave no doubt that volcanoes have existed from a very early period and contributed extensively in preparing the surface of the globe for vegetable and animal existence. The frequent allusion to the phenomena of burning mountains in the Scriptures seems to imply a very early familiarity with their eruptions. I think they are mentioned or alluded to by the sacred writers in texts such as these: Job says, (chap. xxviii. 5,) "As for the earth, under it is turned up as it were fire." "The flame setteth the mountains on fire." (Ps. lxxxiii. 14.) "He toucheth the hills, and they smoke." (Ps. civ. 32.) "Touch the mountains, and they shall smoke." (Ps. cxliv. 5.) The effect of volcanic heat seems in view when Jeremiah prophesies, "The mountains shall be molten as wax before the fire;" and Micah (i. 4) adds, "The valleys shall be cleft as wax before the fire, and as the waters that are poured down a steep place." All the horrors of a volcanic eruption are depicted by the prophet Nahum, (i. 5–12:)—"The mountains quake at him, and the hills melt, and the earth is burned at his presence. Who can stand before his indignation? and who can abide in the fierceness of his anger? His fury is poured out like fire, and the rocks are thrown down by him. With an overrunning flood he will make an utter end of the place thereof, and darkness shall pursue his enemies. While they be folden together as thorns, and while they are drunken as drunkards, they shall be devoured as stubble fully dry. Thus saith the Lord, Though they be quiet, and likewise many, yet thus shall they be cut down when he shall pass through." But, amid such desolation, how full of comfort is the assurance, (verse 7,) "The Lord is a stronghold in the day of trouble; and he knoweth them that trust in him."

Diodorus Siculus mentions eruptions of Mount Etna as having occurred as early in history as in 1693 B.C., or about the time of Joseph. The ancient heathen, as is known from classic authors, believed these mountains to be the residence of the god Vulcan, who, for some misdemeanour, was condemned to forge thunderbolts for his superior's weapons. They were called "Vulcania" by Virgil; and since his time the term volcano has been adopted for all such mountains. Mount Ararat bears evident marks of volcanic origin. Indeed, as granite is found in many localities as if forced up from great depths in perpendicular streams, much as lava is seen to be raised in modern times, Mount Sinai, and other mountain masses of granite, may have been upheaved by volcanic action in very early times. It is evident that there is force enough in a volcano to raise large masses of matter. The volcano Cotopaxi has been known to project a stone one hundred and nine cubic yards in volume to the distance of nine miles. It was the celebrated Von Buch's theory that all volcanoes were burst upward, or tilted from the centre outward all around; but it has been clearly shown that this was a mistake, and that Etna has been built up by successive layers of lava and cinders thrown up around its vent.

When lava cools, it becomes too solid to flow onward; but it cools so slowly that lava ejected from Jorullo, in Mexico, one hundred years ago, is not yet cold; and lava from the same volcano was in motion after the lapse of ten years. The lava from Etna in 1819 moved at the rate of a yard per day nine months after the eruption. Advantage has been sometimes taken of this to save cities from destruction, by breaking a new way for the lava through its hardened walls. The temperature at which lava continues fluid is considerable enough to melt glass and silver, and has been found to melt a certain mass of lead in four minutes, which it required double that time to melt when laid on red-hot iron.

Streams of lava are long in changing their character. You may read in Rollin's History that the Carthaginian army advancing against Syracuse, 392 B.C., were stopped by a stream of lava flowing into the sea from a recent eruption of Etna, and compelled to go round the mountain. That very stream is still distinctly traceable, two miles wide and twenty-four miles long, and has a partial coating of vegetable mould. A scattered forest now growing on it, called the Bosco di Aci, contains many large trees. It is apparent, also, that this stream covered other lavas of a still more ancient date. Stromboli has been recorded as in unceasing activity for the last two thousand years. Its lava never flows out of the top, but always through a side fissure into the sea.

"When lava is quite cold," said Edward, "how does it change into such different substances as those Mr. T—— sent us? Obsidian looks like glass; pitch-stone resembles granite dipped in resin; basalt is a hard, black rock; and cinders and pumice-stone are brittle enough to powder in my fingers."

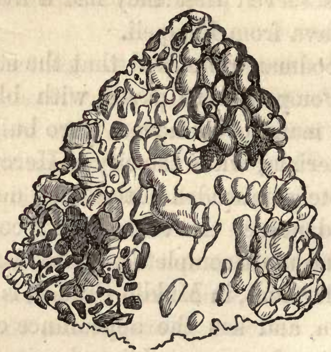
Mr. Goodman remarked that the mere situation and circumstances of different portions of the same stream of lava would naturally cause it to exhibit various appearances from the different times and places of its cooling. That cooled from a perfectly melted state, under great pressure and out of reach of the atmosphere, becomes obsidian, or volcanic glass. It is called obsidian merely because Obsidius was the name of an Ethiopian who brought it first from his country to Rome in Pliny's time. It consists of silica, alumina, potash and oxide of iron, and is, you see, completely vitrified, as if made at the glass-works. A volcano is, in fact, a vast natural glass-manufactory, using the ordinary materials employed in glass-works. Obsidian is of various colours,—but chiefly black or very dark green. If you examine a fragment of your's through the microscope, it seems quite clear, except the tiny air-bubbles such as we see in glass, for it really is natural glass, and in small specimens is quite undistinguishable from that of the glass-house. In Mexico and Peru, obsidian is used for hatchets, adzes and other cutting-instruments, as well as ring-stones and other ornaments; and in Egypt the priests used it for sacrifices long after metal knives were invented.

Here is some more lava, said Mr. Goodman, (picking out a piece,) looking like gray marble, only the markings are more spotted and circular than those of marble generally are. That is lava cooled slowly and quietly, and crystallized. The markings are caused by the different substances mingling with it,—a little metal in some lavas, olivine, leucite, mica, or quartz in others, with a large proportion of felspar, or augite. A predominance of felspar produces light-coloured lava; of augite, darker shades. These lavas are hard enough to be quarried and used for building-purposes. Many varieties will take a high polish, and are pretty enough to be carved into ornaments, tables and boxes.

Alice observed that they had a little book made of lava from Pompeii.

Mr. Goodman remarked that the streets of ancient Pompeii were paved with blocks of lava, and many of its houses were built of the same materials; while the city of Herculaneum is completely imbedded in the stony mass; for, as it stood nearer the volcano, it received the hottest and most completely melted lava. The city of Clermont, in Middle France, is built of black lava, and has the appearance of a city in mourning for some public calamity. Many lavas exactly resemble, in colour, marking and texture, the slags of iron and copper smelting-furnaces, and dispose themselves in heaps of singular form. The colours, black, ash-coloured, gray, blue, or greenish, depend on the admixture of metals. All these compact or vitreous lavas will strike fire; some, especially the dark portions, are magnetic; and all will melt into the same kind of opaque glass.

Those lumps of half-burnt stuff full of holes are specimens of cellular lava, and appear to have been heated only enough to expel the fixed air contained within the clayey particles. These holes, or cells, are now often filled with quartz, agate, or carbonate of lime which has percolated into them and been crystallized there. Sometimes they are almond-shaped, and, when hard enough to be cut and polished as a solid stone, it is called amygdaloid, from the Greek word *amygdala*, an almond. Besides lava, great quantities of scoriæ, or cin-



AMYGDALOID.

ders, are usually produced and ejected during volcanic eruptions. They are either black, brown, reddish, or gray, and, except for the occasional traces of metal, scarcely differ from the cinders of common furnaces. Indeed, glass and metal slags exhibit just these differences, according as they are cooled quickly or slowly, under pressure or exposed to wind and weather.

Lava decomposes under the influence of the atmosphere, and becomes a fertile soil: hence the luxuriance of the vineyards in volcanic regions. The same fertility is seen when the slag of our furnaces has been decomposed by the like cause.

Fine dust and ashes are frequently projected from volcanic craters in vast quantities, so as not only to overwhelm the neighbouring regions, but the lighter particles are often carried hundreds of miles. Sir Stamford Raffles describes a fall of ashes and dust from the volcano of Tomboro, in Sumbawa, in 1815, as destroying substantial houses forty miles off. The eruption was attended with such loud reports as to attract attention at Macassar, two hundred and seventeen miles distant, where it was supposed that pirates were fighting. A ship with troops was despatched to look after them. This ship soon became enveloped in "showers of light dust, which so obscured the light that at mid-day it was impossible to see the hand when held close to the face;" and the ship's progress was impeded by the cinders, pumice and burnt trees and logs floating on the water. The dust penetrated every part of the ship, lying in heaps a foot thick on the deck. It had a faint smell, but was perfectly tasteless, and when moistened formed a tenacious mud, very difficult to wash off. It was therefore a very disagreeable shower to encounter.

Sometimes, when boiling lava is projected high into the air, (as is frequent in Kirauea,) the wind catches it and cools it in thin sheets, or spins it out into delicate fibres, so that it lies like mown grass. The natives call this the hair of Pélé, the goddess who, they believe, presides over this volcano. Sometimes this lava falls amidst forests, and hangs from the branches in the form of stalactites.

When gathered in fibrous masses, it is called pumice-stone, which is used in the arts for polishing metal, wood, pasteboard and stone, and for smoothing parchment. It is continually used, too, by practical philosophers and chemists, for getting ink or any stains off the hands, and it generally makes them feel soft and smooth. Its fibrous make fits it for gently scraping off the outer skin, and, with it, any adhering stains. Pumice is so abundant in the Lipari Islands as to be quarried in large flakes, which are used for roofing; and puzzulana, a sort of half-burnt earth found very extensively in Italy, France, England and many other countries, seems to have been projected from volcanoes, and is useful for building under water. Powdered, it is valued as a cement for lighthouses, &c., as it suddenly hardens when mixed with lime and water, and is extremely durable even when constantly wetted afterwards.

Mr. Goodman went on to say that brimstone, or sulphur, comes from volcanoes too, of which he had brought some specimens from the souffrière at Montserrat. It is found most abundantly in volcanic regions,—especially where the volcanoes are still active. It occurs either as an efflorescence or powder sprinkled on the surface of the ground, or in masses mingled with clay, ashes and other volcanic products. In Sicily there are mines of sulphur, whence it is exported in large square blocks. Great quantities, too, are obtained from the crater of an ancient volcano near Naples, called the Solfatara, where the ground appears perfectly yellow with it. In Iceland, mountains are composed entirely of clay and sulphur, the surface of which is covered with a beautiful crust of crystallized sulphur, varying from a quarter of an inch to several inches in thickness, under which wooden planks are sometimes found covered with crystals; but steam and vapours prevent examination to any great depth. In Armenia the natives shoot down masses of volcanic sulphur from the tall cliffs inaccessible to the foot and hand of man.

Sulphur is also obtained, by collecting it as vapour, from many melted minerals. As it cools, the sulphur descends in a fine powder, or adheres in crystals to any convenient substance. When it is thus artificially procured, the process is termed subliming. Sulphur is used in Britain for making gunpowder, cinnabar and sulphuric acid, and for bleaching straw. It is also used medicinally. Twenty thousand tons are annually imported for our supply. Reports respecting recent eruptions of lava from Vesuvius mention many interesting deposits of sulphuric efflorescence, as well as great quantities of muriate of soda, or common salt, which seems always rapidly formed during volcanic activity.

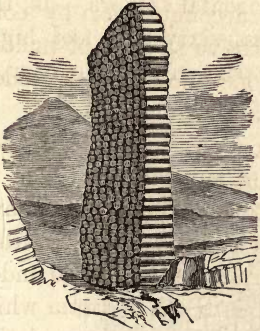
Pitch-stone is a variety of lava composed of felspar and augite, and generally has a greenish tinge and shining hue, as if varnished. Under the microscope it glitters like granite. It more nearly resembles basalt, and is by some considered as an intermediate stage towards that hard rock.

"Oh, Edward," exclaimed Alice, "there was a piece of basalt in the box, and we thought Mr. T—— must have sent it by mistake for some volcanic cinder."

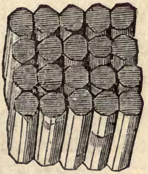
Mr. Goodman replied that it was no mistake; for, since the effects of volcanic heat have been more extensively watched, it seems to explain the origin of many rocks which had formerly greatly puzzled inquirers; and many of these, among which are basalt and trap, are now considered to be of igneous formation,—that is, to have been melted under great heat. Many interesting experiments have been tried by melting basalt and cooling it either quickly into glass or slowly into stone. By adding carbonate of lime, slates and shales have thus been converted into excellent pumice-stone.

The trap—or, in German, *trapp*—rocks are so called from the German word *treppe*, a stair, because they generally occur in a series of steps or terraces, accounted for by considering them as successive streams of molten rock hardened over one another and eroded so as to terminate in abrupt descents.

All the basalts and traps consist chiefly of silica,—although other substances mingle in them in small proportions. They seem to have acquired their peculiar aspect, so different from that of modern lavas, from having cooled under water or been forced into other strata while excluded from the air. Some of the varieties of greenstone, whinstone and millstone are valuable on account of their hardness, either for grinding metals and corn, or for building and paving, and when well broken, they make excellent macadamized roads. They are as durable as granite, though, from their close grain and dingy colour, not nearly so pretty. Basalt occurs in many parts of the world among ancient igneous rocks, forming the isolated caps of hills, and resting upon other rocks, as if it were part of some great sheet, the most of which has been destroyed. The largest space it occupies continuously seems to be in India, where there are outspreading rocks of it covering an area of two hundred thousand square miles.

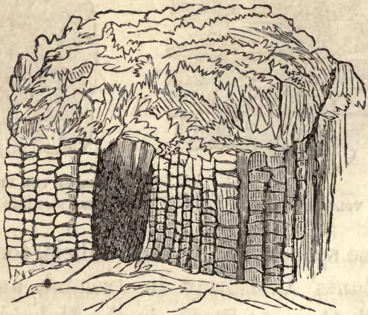


VOLCANIC DIKE.



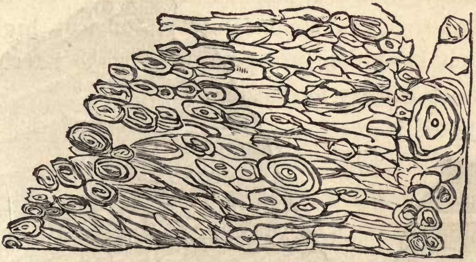
PORTION OF THE DIKE, SHOWING ITS BASALTIC PRISMS.

These specimens, by their labels, come from the Giants' Causeway in Ireland, and from Fingal's Cave, at Staffa, in the Hebrides; but they look very much alike; and, indeed, those localities are both remarkable for their long ranges of regular-shaped columns. Similar basaltic columns are found in a valley of the Vivarais, in the south of France, and near Vicenza, in Italy, and seem to have been caused by a kind of coarse crystallization, owing to the slowness with which the melted basalt cooled. Some of these columns are upright, and appear jointed as accurately as if by the stonemason's rule; others are curved as if they had crystallized while in motion. They are also occasionally seen in horizontal layers,—as the chimney of St. Helena, sixty-four feet high, which is evidently a portion of some narrow dike of similar formation.



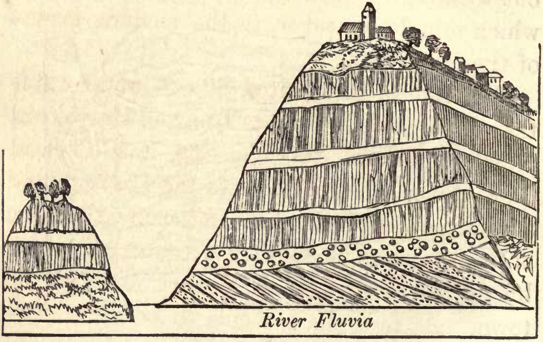
CHEESE-GROTTO.

Sometimes the basalt assumes the form of a perfect globe, so that the rock seems made of a pile of cannon-balls; in other instances these balls are flattened, and stand one upon another, like a pile of cheeses, as is the case with the pillars of the cheese-grotto between Treves and Coblentz. Many other rocks assume this globular form. Greenstone and pitch-stone sometimes exhibit it when decomposing. On Ascension Island, and in one of the Ponga



GLOBIFORM PITCH-STONE.

Islands of the Mediterranean, are rocks full of these balls, varying in size from a few inches to three feet in diameter, some of which, after exposure to the weather for a short time, will scale off at a touch into numerous concentric coats, like those of an onion, enclosing a compact nucleus in the middle; but a few harder blows will make this too shell or scale off like the outside. Those in Ascension Island have a compact, hard shell, with a hollow interior, and are called volcanic bombs. The river Fluvia, in Spain, cuts through a bed of ancient lava to the depth of about one hundred and thirty feet. On the edge of the precipice stands the town of Cassell Follit. The cliff is so abrupt that its composition is easily visible, and it seems that the lava immediately under the town is scoriaceous or cindery; under that is spheroid basalt,—that is, basalt in a globular form. Beneath this is a more compact basalt, with crystals of olivine. There are five distinct layers of basalt in all,—the uppermost spheroid, the rest prismatic or columnar,—each separated by thinner layers more compact.



SECTION OF CASSELL FOLLIT.

Most probably they were formed by successive flows of lava, either during the eruption, or at different periods. The whole mass rests upon alluvium, ten or twelve feet thick, consisting of pebbles of limestone and quartz, but without any mixture of the igneous rocks, which mingle, however, in the modern gravel of the same river.

We have in the United States innumerable trap dikes, such as Mounts Tom and Holyoke at Northampton, in Massachusetts, East Rock at New Haven, the Palisades of the Hudson, and a hundred other hills, almost deserving the name of mountains, along the belt of country occupied by the red sandstone of Newark and Norristown. At first there seems to be some close connection between this kind of rock and the trap dikes. But we find multitudes of little dikes penetrating the country on each side, the Highlands or Blue Ridge, and the Philadelphia, and Baltimore and Richmond hills, to the southeast. In the iron-mines of New Jersey and Pennsylvania small straight walls of greenstone trap are left exposed, standing at intervals across the pits. But the trap hills of the New Red country seem to have been formed by this ancient lava having lifted up the layers and flowed out sideways. When their edges were washed away, the prismatic crystals of lava, much ruder and larger than those of the Giants' Causeway, were left to show themselves; and when the sun is right for it, these are to be grandly seen, like mighty columns, upon the face of the Palisades.

Great outbursts of trap accompany the copper-ores of Lake Superior; and many more occur in Canada. Trap is a very common rock in the great West beyond the Rocky Mountains, where it lies in level sheets, forming mountain-terraces.

Edward asked what would happen if hot lava passed through or over any rock that was easily changed by heat.

That has been thought of and investigated, said Mr. Goodman; and great changes have been observed. For instance, a greenstone dike, or vein, passing through a bed of coal in Antrim, has reduced it to a cinder for the space of nine feet on either side. At Cockfield Fell, in the north of England, a similar change is observable near a dike of trap,—the coals near to it being perfect coke, while those immediately touching it are converted into a substance resembling soot. At Salisbury

Crag, near Edinburgh, a sandstone which comes in contact with greenstone is changed into a sort of jasper. In other places, chalk has been chânged into fine marble, red sandstone into hornstone, clay-slate into flinty slate, by the heat of some melted rock which has intruded into those substances; and these changes have exhibited every stage of progress, from the distinct materials on either side, to the unchanged molten rock in the centre of the dike. These changes are easily understood by any one who has watched the effects of fire and heat in potteries or glass and metal furnaces, or of heated and acid waters in chemists' vats.

It seems likely that volcanoes must have existed almost everywhere in the world at some time or other, since so many different rocks are produced by their influence; and now, if you will just take a map of the world, and mark out with any colour the regions where volcanoes are known to be still active, you will be astonished to find the long line of vents you must mark on the edges of the continents, not only on the side of the Atlantic Ocean, but thickly scattered in both the Indian and Pacific Oceans; while if you use a second colour, to distinguish the regions of extinct volcanic action, you will add a large portion of Europe, Asia Minor, Persia, and the Holy Land; and in China the natural springs of gas and naphtha induce the belief that volcanic action was formerly powerful there.

All the young people were struck with this remark, and declared they would make maps of that sort for their own gratification.

Mr. Goodman remarked that tuff, tufa and trass are other stones, produced by the concretion of the ashes, or fine powder, ejected from volcanoes, and falling either into the sea or on the earth, where it gradually becomes, by the influence of the weather, hardened into masses firm enough to take a beautiful polish. Sometimes they contain shells, and are then accounted more curious and valuable. Many garnets, agates and other pretty stones are formed in volcanic regions, and are sold at Naples as gems from Vesuvius. They generally consist of silica and alumina, and are not essentially different from Oriental precious stones. Many gases generally escape when volcanoes are in eruption. From the mingling of these water is often formed, which, descending in showers of hot rain, transforms the lava into mud. Noxious vapours, called mofetes, frequently break out from old lavas before new eruptions occur. These vapours often fill the wells and pits in the neighbourhood, and so affect the throat and nostrils that they soon prove fatal to men or animals imbibing them.

With regard to the fire that supplies the volcanoes, various conjectures have been formed on the subject, and many interesting experiments tried, to prove whether there is any store of fire in the centre of the earth, or whether volcanic combustion arises from the meeting of gases usually kept apart; but nothing is yet ascertained. Believers in revelation, however, know from God's word that the element of fire, unmanageable as it is by men in any volume, is under the perfect control of its great Creator; and, having his own assurance of his superintending care and protection, we may feel perfectly safe in his keeping; for even if this earth and all that is therein should be burned up, and melt with fervent heat, there will remain the promised new earth and new heaven, wherein dwelleth righteousness, and where all true believers in the Saviour will be in safety and peace forever.

CHAPTER X.

GEMS.

A VALUABLE cabinet of minerals was left as a legacy to a friend of Mr. Goodman's, and his young people were soon invited to inspect it,—when they rejoiced in the opportunity of seeing many specimens of which hitherto they had only read. One compartment contained a brilliant collection of gems, at which Alice exclaimed,—

"Oh, Mrs. B——, why do you not have those beautiful things set in gold, and wear them as ornaments?"

"Nay, my dear," she replied: "they would then only be trinkets for my personal ornament. Now, collected here and seen in their native simplicity, they are more useful as specimens of God's abundant power and bounty in forming objects of such beauty even under ground; for they are but stones, valued chiefly for their rarity, or the difficulty of raising them from their hidden homes."

This remark made a great impression upon Alice; and she failed not to repeat it to her father in her glowing description of Mrs. B——'s gems.

Mr. Goodman rejoined that these glittering jewels are but stones; yet their natural beauty is so admirable, their durability so prolonged, and the difficulty of obtaining them so great, that in all ages of the world they have been accounted precious by man, and represent wealth in small compass. Even the patriarch Job speaks of "the precious onyx, the crystal, the sapphire, the ruby, and the topaz of Ethiopia," as ornaments of the highest price for the "jewels" and "diadems" of his day. (Job xxviii. 16–19.) Every collection of Egyptian and Assyrian antiquities proves that the twelve varieties of gems set in the Jewish high-priest's breastplate (Exod. xxviii. 17, 20) were well known, and comparatively abundant, in the earliest periods of civilization; while Tyre (Ezek. xxviii. 13) traded in diamonds, sapphires, emeralds, the sardius, onyx, topaz, beryl, jasper and carbuncle, not only for ornament, but use; and Jeremiah's assertion (xvii. 1) that "the sin of Judah was written with the point of a diamond," indicates that a pen, or writing-style, of such material, was not uncommon.

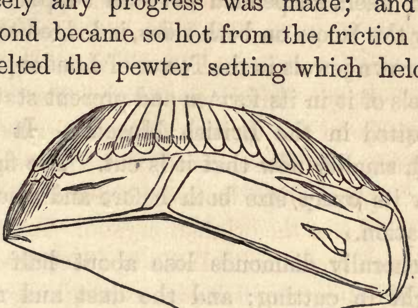
Edward inquired whether these stones are found in mines and veins, like metals, remarking that he had read of diamond-mines.

Mr. Goodman said that there are diamond-mines, certainly; but they are found very frequently in detached geodes, or hollow nodules of agate, enclosing crystals of various sorts, or only a drop of water or morsel of bitumen. The diamond geodes are generally in the rocky regions of tropical countries only. Brazil and Golconda have hitherto yielded the principal specimens,—though lately some have been found in the Uralian Mountains of the more temperate zone. Some diamonds have been found in North and South Carolina, in connection with a very curious sandstone called *Itacolumite*, which can be bent, and even stretched like India-rubber, a very small distance, feeling to the hand as if its grains of sand were jointed or hooked into each other. The largest (supposed) diamond ever found in the United States, weighing twenty-four carats, was said to be found in the gravel near Richmond. The alluvial deposit of gravel and sand on the river Jenquetinhonha, in Brazil, contains so many of these gems that regular works are established for washing them out of it. The largest ever known was found there, (if it is indeed a genuine diamond,) and belongs to the sovereign of Portugal: it weighs sixteen hundred and eighty carats. A carat weighs four grains: consequently this diamond must weigh more than eleven ounces.

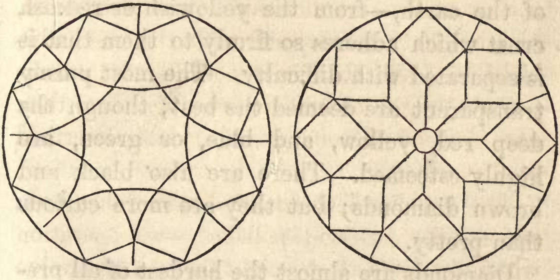
The next in value was found in India, and was formerly the eye of an idol in Malabar, from which it was stolen by a French soldier, and, after passing through several hands, was eventually, in 1776, purchased for the Emperor of Russia, and now adorns the sceptre of that country. Four large uncut diamonds formed the clasp of Charlemagne's cloak.

The famous Koh-i-noor diamond was one curiosity at the Great Exhibition of 1851; but most people were disappointed in its appearance. However, much depended upon the time of day and sort of weather in which it was examined: its beauty was most apparent between two and three o'clock, when the sun's rays fell upon it. This "mountain of light," as its name implies, belonged to Runjeet Sing, and was deemed so valuable that, when worn, other jewels were dispensed with. It was given up to the East India Company for the Queen of England when the Punjaub was surrendered, and, in its rough state, appeared to be only a portion—about one-third—of the original crystal. Tavernier, a French traveller to India in 1676, describes the Koh-i-noor of his day as weighing much more and being broken or cut into separate pieces. Two diamonds, one in Coochan, and the great Russian diamond I just mentioned, so singularly correspond with the one exhibited in 1851, that it is considered by competent judges as not improbable that they once formed the one great crystal described by Tavernier.

The Queen's Koh-i-noor diamond has been successfully cut and polished,—an operation which occupied thirty-eight days, with twelve hours' work per day, without intermission. There were one or two flaws which it was desirable to remove; and some parts of the stone were so extremely hard that in six hours' time, with the wheel revolving two thousand four hundred times per minute, scarcely any progress was made; and the diamond became so hot from the friction that it melted the pewter setting which held it; and the mill itself was so heated that particles of iron mixed with the diamond-powder and oil became ignited.* The dia-



KOH-I-NOOR DIAMOND BEFORE CUTTING.



UPPER SURFACE. AFTER CUTTING. UNDER SURFACE.

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* Report from Messrs. Garrard, the lapidaries, 1852.

mond itself, suspended between supporters to show the facets on both sides, is lodged among the crown jewels in the Tower of London, while models of it in its former and present state are deposited in the British Museum. It looks much smaller now that it is cut. The figures show its exact size both before and since the operation.

Generally diamonds lose about half their weight in cutting; and the dust and refuse are worth fifty pounds an ounce. The beauty of diamonds is not visible when first dug out of the earth,—from the yellowish or reddish crust which adheres so firmly to them that it is separated with difficulty. The most purely transparent are deemed the best; though the deep red, yellow, and blue, or green, are highly esteemed. There are also black and brown diamonds; but they are more curious than pretty.

Diamonds are almost the hardest of all precious stones, and are by some supposed to be the "adamant" of the ancients. They can be cut and polished only by diamond-dust. Small ones, called natural sparks, are found abundantly in the sand of the river Gonal, which runs from high mountains into the river Ganges. When its waters have subsided and cleared after the heavy rains of December, the whole population search for diamonds. The most promising spot is selected, when the sand is dammed up and carefully examined, all the labourers being watched, to prevent the gems being swallowed,—which is the usual method of concealing them. All work without clothes. It is said that in ten thousand diamonds only one is found weighing more than twenty carats, as, though numerous, they are generally exceedingly small.

Diamonds are distinguished from other gems pretty accurately by their hardness, form of crystal, and other properties, also by their chemical composition. Each gem crystallizes in certain forms exclusively, so that frequently its form at once determines its nature: when found in various shapes, they are usually parts of the original or perfect figure. The diamond when rubbed phosphorizes, and becomes positively electrical, and is therefore a non-conductor of electricity; when heated without the contact of air, it suffers no change; but, if ignited in contact with air, it is totally converted into carbonic acid gas.

"Isn't that very strange?" said Edward.

Mr. Goodman replied that in this respect it differs from all other gems. Chemists have proved that it actually consists of crystallized carbon, and therefore is naturally consumed by fire, while other gems resist its influence, and are often recovered from the ashes after fires have destroyed the jewel-boxes.

Alice asked if the chemists can turn carbon into diamonds.

They have not yet entirely succeeded,—though they have produced very beautiful crystals. The peculiar brilliancy of the diamond is owing to its great power of reflecting light. It writes on glass, as you know, and scratches all known minerals. Hence, glaziers use it for cutting window-panes. The black, dirty and imperfect diamonds are powdered for grinding and polishing other gems; and small portions are used as pivots for the delicate wheel-work of watches. The Hindoos value diamonds, and some other gems, as charms, beyond all money price; and they are pierced, and worn about the person as talismans to preserve from lightning, to avert danger, dispel melancholy, or inspire courage and insure honour and riches.*

Diamonds are found in certain particular, though diversified, forms. Sometimes they are in rolled pieces, which of course need cutting or grinding into shape. They also occur in fourteen variations of crystals, either cubic, pyramidal, or octahedral. They are generally cut, either by sawing with a very fine saw of soft iron, while the diamond is kept well moistened with diamond-dust and vinegar, or they are ground on a fine wheel, which is worked at the cutter's discretion; but it is always a very slow process.

The other precious stones, such as rubies, sapphires, emeralds, &c., may all be divided into two classes, aluminous and siliceous stones,—or those consisting chiefly of alumina, varied by small proportions of other substances, and those made of silica, that is, flint, with similar or different mixtures of other matter; and they are found, like the diamond, in detached nodules, in alluvium or earthy beds.

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* See "Oriental Accounts of the Precious Minerals." Translated by Raja Kalikishen, with Remarks by James Princep, F.R.S., in the "Journal of Asiatic Society of Bengal." Calcutta, 1832.

Out of these two classes of gems, the aluminous stones comprise perhaps (next to the diamond) those on which men set the highest price; and the most precious of these are the Oriental sapphire, ruby and topaz. I mention these together, because they really are varieties of the same thing,—corundum,—consisting almost entirely of alumina, with a little lime and oxide of iron; but the proportions differ slightly with the colour. Sapphires are found amidst gravel near trap rocks in Bohemia, Saxony and France, Scotland and the East Indies; but the most beautiful come from the Capelan Mountains of Pegu. They occur in blunt-edged pieces, roundish pebbles, or crystallized in various pyramidal forms. The colours are blue, red, gray, white, green and yellow. Next to the diamond, the blue sapphire is the hardest substance in nature. When heated, it becomes snow-white, and exhibits so great a degree of lustre that it is often substituted for diamonds. The sapphire was one of the stones in the high-priest's breastplate, and is mentioned in Revelation as one of the foundation-stones of the holy city. It is frequently spoken of in the Scriptures, not only as a precious stone for jewels, but as the most splendid article for thrones and pavements: so that learned men suppose that two substances were intended by the Hebrews under the ancient and general name of sapphire.

The other substance which may be meant is the blue stone called lapis lazuli, found in veins of the rocks of China, Persia, Bucharia and Lake Baikal. This was highly valued in Egypt for toys and ornaments, and was often used in mosaic-work for the walls and floors of palaces, as noticed in Exodus xxiv. 10, where it is said that Moses and the seventy elders "saw the God of Israel; and there was under his feet a paved work of a sapphire stone, and as it were the body of heaven in his clearness." Now, our sapphire is never found except in small crystals, while lapis lazuli, or azure stone, occurs in large slabs, suited for costly pavement, and is, moreover, an opaque sky-blue, interspersed with gold points,—which gives a peculiar aptitude to its comparison with the starry heavens by Ezekiel, (chap. x. 1.) This description really adds much to the beauty of the allusion; or rather, a knowledge of the substance referred to shows the appropriateness of the figure.

Lapis lazuli consists of nearly equal parts of silica and alumina, and a considerable portion of soda, with a little sulphur. It has been used to form a brilliant blue paint from very early times, and was the costly ultramarine of the middle ages. Ultramarine is now produced artificially so cheaply that as much can be purchased for twenty-five cents as formerly cost twenty dollars.

But the blue crystal sapphire was a gem also known to the ancients, and was, most likely, that used for the high-priest's breastplate, as it is more suited for engraving than the softer lapis lazuli. Sapphires are preferable to rubies for jewelling watches, on account of their uniform hardness. Some are variegated in colour, half red and half green, or striped with yellow. When very pale, they are termed white sapphires. The asterias, or star-stone, is a beautiful variety of sapphire, exhibiting a rayed opalescent lustre.

Rubies are considered very beautiful, as well as valuable. They are composed of the same material as sapphires, but are not quite so hard. They are prized for their deep-red colour. "Polished as sapphires," "ruddy as rubies," the prophet Jeremiah describes the Nazarites in their prosperity. (Lam. iv. 7.)

The carbuncle, nearly purple; spinel, corn-poppy scarlet; balas, pale red, inclining to violet; and the rubicele, of a reddish yellow, are all considered varieties of the ruby. The ruby in the English crown, about the size of a walnut, was brought from Spain by Edward the Black Prince. One hundred and eight are mentioned in the throne of the Great Mogul, weighing from one hundred to two hundred carats, and one round one weighs two and a half ounces; but a ruby weighing only six carats, or twenty-four grains, is, if perfect, often valued at one thousand guineas.

The topaz has a small admixture of fluoric acid in its composition, and is naturally of a brilliant yellow, but can be changed by heat to rose red, violet blue, or white; but then it loses its transparency. It is so abundant as to give its name to the topaz mountain rock, of which the mineral forms a part. Occasionally it is found in granite; and nests of topaz have been discovered in clay-slate, or in veins with tin-stone; but the best occur in large crystals of oblique prism-shape, amidst the alluvial soil of granite districts. The East Indies yield the finest topazes, being no other than the yellow sapphires already mentioned.

Next in value are those from Brazil and Peru. Inferior topazes are common in Siberia, Saxony, Bohemia and Scotland. In Scotland a yellow or brownish quartz, called cairngorm, from the mountain of that name, is much used for seals, brooches, rings, &c. Crystals of topaz refract double.

Emery is bluish-gray corundum mixed with iron, and derives its name from Cape Emeri, in the Isle of Naxos, whence it was first brought. It is used for polishing iron and steel. It will interest you to look at some emery-powder through the microscope.

Several other gems are composed chiefly of alumina; for instance, the garnet is alumina, with nearly equal proportions of silica and oxide of iron, crystallized in three different forms, pyramidal, dodecahedral and prismatic, and yielding fourteen varieties of garnet, each of which is distinguished by some name indicating its colour, locality, or origin. The precious or noble garnet is a dark bluish-red. The finest come from Pegu; but many are found in the northern countries of Europe,—generally in small crystal grains, though occasionally in masses. It melts to a cinder under the blowpipe, and is not very valuable. The coarser kinds are used for beads, or even, as emery, for polishing metals and gems.

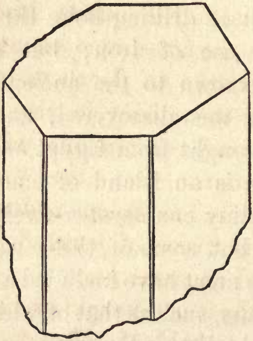
Vesuvian is a species of garnet found in abundance among the unaltered rocks ejected from the volcano: it is green or brown. Egeran, reddish brown; gehlenite, green, from the Tyrol; pyrope, a blood-red variety; pyreneite, grayish black, from the Pyrenees; grossulare, green; melanite, velvet black; colophonite, orange-red; helrin, wax yellow; and cinnamon-stone, are all varieties of garnet. Though these stones are of such different colours, they are considered varieties only of the same substance, because their chemical composition is either precisely the same, or only slightly varied by very small admixtures in different proportions of iron or manganese, which produce the different colours.

Cyanite, or kyanite, is another aluminous gem, with a large proportion of silica and a little iron and potash. It is found in masses as well as in distinct crystals in the granite and mica-slate rocks of the oldest formation, in most countries both of the Old and New World. Its principal colours are Berlin blue, gray and green. Some specimens are quite transparent, others very nearly so. In India it is cut and polished as an inferior sort of sapphire.

The chrysoberyl is a bright, green gem, usually found in round pieces about the size and colour of a pea, but sometimes in crystals. It consists almost entirely of alumina, with a small proportion of silica, and a very little lime and oxide of iron. It refracts double, and becomes electric by friction. It is found in Brazil, Ceylon, Siberia and Connecticut, and can be so cut as to give twenty-eight facets to the summits of the prism-shaped crystals.

The pretty blue turquoise is a stone hitherto found only in Persia, where it is highly prized for ornament. It occurs in considerable masses, and in various shapes, among rocks of iron. There is a variety, called bone turquoise, found occasionally in Languedoc, and once supposed to be the tooth of some animal penetrated with copper-ore. It really is composed of phosphate of lime (the same material of which bones are made) and oxide of copper; and probably the notion of its being teeth arose from its shape and ivory-looking texture.

I have not yet mentioned those pretty stones emerald and amethyst, because they, with many others, are siliceous gems. The emerald, as a gem, is valued next to the ruby, and consists of about two-thirds of silica, some alumina, and a little lime, glucina, and oxide of chrome, with a very little water. The most beautiful come from Peru and Brazil, where the natives had the wonderful art of drilling holes through them without the use of iron; but an inferior species was known to the ancients long before America was discovered, and seems to have been brought from Egypt and Bombay. Indeed, there is an island of emerald in the Red Sea. Pliny enumerates twelve varieties of emerald; but some of these were so very large, that he must have included a green spar, or natural glass, such as that of which the celebrated emerald dish at Rome was made. Theophrastus, a pupil of Aristotle, in his treatise on stones, describes one four cubits long and three broad, also an obelisk forty cubits high and from two to four broad, which consisted entirely of four emeralds, as he calls them. The true emerald gem, however, only occurs in such very small crystals that any of the size of a walnut are considered extraordinary specimens. A very large one, weighing eight ounces eighteen pennyweights, is in the possession of the Duke of Devonshire. It came from Granada, and is two inches long and two and a quarter inches in diameter. Here is a drawing of it. At Loretto there is shown a shrine studded with more than one hundred of these brilliant stones. When heated, emeralds change into blue, but recover their natural green colour on cooling; but they do not stand fire well, and under very great heat fuse into white glass.



DUKE OF DEVONSHIRE'S EMERALD—HALF SIZE.

Beryls are found in Siberia, France, the United States and Brazil. They differ very little from the emerald except in colour, varying from bluish green to honey yellow, sky-blue, and even brown. Ancient naturalists attributed all sorts of wonderful properties to the beryl,—such as keeping people from falling into ambuscades, exciting courage in the fearful, and curing diseases of the eyes and stomach. "It does none of these things now," concludes the quaint historian, "because people are not simple enough to believe it has the virtue to do them." The beryl was one of the stones in the high-priest's breastplate, and is often alluded to in Scripture as in common use, either "in gold rings set with beryls," as Solomon describes, or in brooches and "rows of jewels." It is sometimes termed aquamarine.

The amethyst is a purple or violet coloured gem of remarkable brilliancy. It is pure quartz, and found in both the East and West Indies, Persia, Brazil, and some parts of Europe. It is much used for seals and brooches. Some of the ancient cups and vases were made of it, as it was an opinion among the Persians that wine drunk from such vessels would not intoxicate: hence its name, from the Greek word *amethystos*, (not intoxicating.) Some writers derive its name from its colour, which resembles that of wine mingled with water. It also was in the high-priest's breastplate, and is mentioned as one of the foundation-stones of the holy city.

In the Bible we read of onyx, chalcedony, sardius, jasper, sardonyx, and chrysoprasus, as "precious stones" in ancient times. I think I told you before that agates and chalcedonies are both of flinty origin. The pretty pebbles called agates derive their name from the river Achates, in Sicily, where they were first noticed, and where they still abound. They have a considerable mixture of earth in them. Agate is not deemed very valuable, and occurs sometimes in such very large pieces that cups, handles of knives and forks, plates, and chemists' mortars can be made of it. The high altar of Messina is entirely encrusted with agate. It often exhibits curious representations of men and animals. One is described by De Boot, in which one side of a circle appears as exact as if drawn by compasses, in the centre of which there is a bishop. Turning the stone round, other men and women appear. Some agates containing the numbers 4191, 1910, &c. are termed arithmetical agates. Agates were so early used by engravers that they are considered a sort of antique gem, and are now rather more regarded for their history than their beauty. Mr. Layard found many agate, onyx and cornelian cylinders among the ruins of Assyria, some of which were covered with elaborate engraving.

Many remarkable specimens of agate are preserved in cabinets; and amusing mistakes have occurred in interpreting the figures upon them. For instance, in an ancient church of France, an agate had been preserved from time immemorial, considered to represent Adam and Eve, with the tree, serpent, &c.; but on further examination it proved to be Jupiter and Minerva, with a modern inscription in the Rabbinical character. An onyx agate, set in a ring belonging to the Earl of Powis, contains the chrysalis of a moth: so that it seems as if these stones were rather suddenly crystallized from a fluid state. The ancient Italian artists were particularly skilful in taking advantage of these natural marks, and worked onyx and agate into those stones called cameo, or camaieu, a name derived from the ancient Oriental word, *camebuia*, given to those onyxes having a second colour. The term is now applied to any stone on which there appears a picture in the natural veinings, or which is artificially produced.

Chalcedony takes its name from the city of Chalcedon, near which it was first noticed and still abounds; but it is also found in Iceland, the Faroe Isles, the Scotch Hebrides, the Pentland Hills, and Derbyshire and Cornwall, in nodules, veins and masses. Chalcedony consists of pure silica, with a very little water. In colour, there are various shades of white, gray, yellow, brown, green, and blue. It is semi-transparent, and harder than flint: moreover, it will not melt. The green variety is used by jewellers, and termed chrysoprasus. The heliotrope is blood-red, or scarlet. The finest specimens come from Bohemia and Siberia. The true onyx is really a chalcedony composed of white, black and brown layers, so as to exhibit a banded appearance in cutting and polishing.

Curious stones, called beekites, are found on the shores of Torbay, England, consisting of chalcedony deposited on a nucleus of coral or fragments of limestone. They vary from the size of beans to nodules a foot in diameter, and, though irregular, are more or less round in shape. The nucleus is often loose enough to rattle, or is in powder. The beekites hitherto examined occur amidst the conglomerate of ancient beaches formed from the new red sandstone, among the fossils of which corals predominate. They derive their name from Dr. Beeke, who first reported their existence and nature.

Plasma is a green variety often found among the ruins of Rome. The sarde and sardonyx are also chalcedonies, or, perhaps, more properly, varieties of cornelian, which has a small portion of alumina and oxide of iron added to its large amount of silica.

Carnelian, or cornelian, is so named from the flesh colour of many specimens, though it is often variegated from pure white, with all shades of yellow and red. It is semi-transparent and very brilliant,—softer than chalcedony, and therefore easily fashioned into beads, brooches, seals, rings, &c. The finest come from the East Indies, where they occur as gray or blackish olive nodules in the beds of torrents. After some weeks' exposure to the sun, they are subjected to heat in earthen pots, which produces the brilliant tints desired by the jeweller. I believe many of these stones have their beauties curiously developed by soaking in oil, and baking or boiling, before they are cut by the lapidary.

Opal is another very pretty and delicate-looking stone of various aspects. The precious opal is simply silica with a very little water. It is valued for its beautiful play of many colours. It is found in small veins amidst the clay porphyry of Hungary or the trap rocks of Ireland. It is generally translucent; but some opals become quite transparent when immersed in water: these are called hydrophanes, or changeable opal. They must be quickly withdrawn, however, on becoming transparent, as otherwise the pores soon fill with earthy particles from the water, and the changeable property is lost. There are six other kinds of opal, produced by the addition of oxide of iron in small proportions, namely, the common, or milk-white opal; the fine opal, so named from its brilliant red hue, which is peculiar to Mexico. Central America, especially Honduras, yields the fire-opal in large quantities, in veins. Mother-of-pearl opal, or cacholong, from the river Cach, in

Bucharia, much resembles mother-of-pearl in colour, though not in texture. The semi-opal is white, gray and brown, mingled as spotted, striped, or clouded: this has a little alumina, carbon, ammoniacal water and oil of bitumen in its composition. Silica and oxide of iron, in nearly equal proportions, with a very little water, produce the ferruginous opal, or jasper ore, of scarlet and gray colours. Wood-opal is found in branched pieces of many various shapes.

Opals change their colour by breaking, and are easily imitated in glass. The ancients had an unaccountable passion for them. The Oriental opal was esteemed double the value of a sapphire of the same size. The senator Nonnius, who possessed the famous opal of Rome, worth twenty thousand sestertii, preferred banishment to selling it to Antony.

You must not confound the jasper mentioned in Scripture with this variety of opal; for jasper opal is only found in Hungary, and, consequently, was unknown to the Scripture writers. They refer to a sort of quartz, found abundantly in the loose sands of Egypt, and still known as Egyptian jasper, of red and brown colours of various shades, disposed in ring-shaped marks. There is also striped jasper, with green, gray and yellow stripes, found in Saxony and among the Pentland Hills. Occasionally, on breaking a jasper pebble, the colours are so disposed as to afford very tolerable portraits of famous individuals. The poet Chaucer and the Duke of Wellington, and others, have been thus perceived.

Porcelain jasper is curious, and supposed by some naturalists to be actually clay-slate baked or burned by volcanic heat; and, as it is found where igneous veins have intruded through beds of coal, this supposition seems plausible. Common jasper and agate jasper seem generally to form part of agates. All the jaspers are hard, capable of bearing a fine polish, and are, therefore, much used for ornament. The Egyptian room at the British Museum shows how much it was used for these purposes by the civilized ancient world.

Alice remarked that they saw some curious stones—gray, green, brown and red, called cats'-eyes—in Mrs. B——'s collection, and inquired what they were composed of. Mr. Goodman told them that cats'-eye stones are brought from Ceylon, and are chiefly silica; but alumina and lime in very small quantities are disposed in the fibrous manner that suggests their name. They are used by jewellers, and highly prized by gem-fanciers. When the late King of Candy's jewels were sold in London, in the year 1820, a cats'-eye two inches in diameter was sold for two thousand dollars,—which seems a large sum for such a stone, as it is more curious than beautiful.

Magnesia combined with silica produces some pretty gems, though not yet commonly used, such as the green ligure of the Apennines; the yellow chondrodite, or brucite, of America, and the purple, brown, red or green stones called tourmaline by the moderns, and lyncurium by the ancients, who not only used it as a gem, but were aware of its electric properties when rubbed. Tourmaline seems plentiful in Ceylon, and is chiefly valued now for its remarkable property of absorbing one of the coloured rays of light and transmitting all the others, so that it is much used for experiments in optical science.

"I suppose," remarked Edward, "that new gems are often discovered, with all the mining that is going on in the present day."

Surely, answered Mr. Goodman. I have not pretended to describe all. Zircon is one of these gems, sometimes called the jargon of diamonds. They are of various colours. Some are named jacinths; and the brightest purple ones have long been known as hyacinths. They are found, in the sand of rivers, or veins of platina, in Ceylon, France and Bohemia, and are composed chiefly of the elementary oxide called zirconia, with about one-fourth of silica. The fluor-spar of Derbyshire, and the green copper-ore called malachite, are much used for ornamental purposes, and are very pretty,—though rather too soft to be ranked as gems. Coral and pearls, too, though products of animal origin, add much to the beauty and value of a jeweller's stock.

You may, perhaps, have read in Eastern tales of the bezoar as a valuable stone; but that is merely a concretion found in the bodies of many animals, consisting, like coral, entirely of phosphate of lime, or magnesia. Its name is Persian, and signifies an antidote to poison, —for which imaginative property it was once highly esteemed. The Oriental bezoars consist of concentric layers, smooth, soft and finely polished. They burn and melt by fire. Three were sent by the King of Persia as a present to Napoleon, which seemed to be composed mostly of woody fibre agglomerated by the animal process of digestion.

Referring for a moment to the twelve precious stones in the Jewish high-priest's breastplate, on which the names of the twelve tribes were engraved, that he might "bear them on his heart" when he went into the holy place to confess their sins and make intercession for their pardon, it is remarkable that eight out of those stones, the sardius, topaz, diamond, beryl, jasper, sapphire, emerald and carbuncle, are mentioned by Ezekiel (chap. xxviii. 13) as having been in Eden, as well as the onyx, which is the first precious stone named in the Bible. (Gen. ii. 12.) In addition to these, the chalcedony, chrysoprasus, jacinth and amethyst are represented as forming the foundations of the holy city in John's Revelation. The mind may thus be carried back to the earliest times,—as if to assure us that men from all ages, as well as from all nations, should be remembered by the Saviour, our great High-Priest, and that all who trust in him shall be furnished with a title for the holiness and happiness of eternal life.

CHAPTER XI.

FOSSILS.

THE soil of the county in which Mr. Goodman's house was situated abounded with fossils; and one of the most popular writers on them was sometimes his guest. The attention of his family was, therefore, early turned to their consideration, and curiosity was excited long before the children were old enough to take any intelligent interest in their construction or their origin. As they grew up and travelled through their own and into other countries, similar remains attracted their attention,—particularly in visiting Trenton Falls and Sharon Springs, in New York, the Bedford and Sulphur Springs of Pennsylvania and Virginia, and the falls of the Ohio, at Louisville,—all famous localities for the collection of these remains, as well as places of resort for health and recreation in the summer season. When, some years after the date when our story begins, Edward made a short voyage to England with his uncle, during one of his college vacations, he had occasion to compare these with an equally celebrated locality for fossils,—a certain hill near Dudley, in Staffordshire, called the Wren's Nest. This hill, though nearly in the centre of England, and far distant from the sea, is almost entirely composed of small marine corals and zoophytes, grouped together in the utmost confusion, many of them exhibiting remarkable elegance of form when a little cleared by dissolving some of the lime-surface with acid.

In completing the "friendship-grotto," some beautiful specimens from this Wren's Nest, as well as from the coral crags of Suffolk, the encrinites of Llangollen, and fossils from places much nearer home, which had been forwarded by different friends, were so used that a corner of the grotto was entirely filled with the ancient memorials of by-gone times. One day, when Edward was watching a marble-cutter at work, a very large oyster, with both shells complete, had been disclosed in the very middle of a block of compact white marble. The owner presented it to him; and this occupied a conspicuous place in the collection, together with an assortment of fossil woods Mr. Goodman had from Antigua, in the West Indies.

Having gone over the other parts of the grotto in their mineralogical inquiries, the fossil-corner now came under review, and the young people gladly hailed a leisure hour, when their father offered to tell them what he knew upon the subject. They were looking attentively at the specimens from the Wren's Nest when Mr. Goodman joined them, and were talking eagerly of the marvel that sea-shells should be found firmly imbedded in rocks so far inland. They at once propounded a host of questions to him.

He told them that our earth had undergone so many revolutions, even since man has inhabited it and recorded its changes, that we need not be surprised to find the remains of sea-shells in places now far inland. Indeed, it is believed that scarcely any part of the known world is entirely destitute of fossil remains.

Edward here remarked that he supposed the word "fossil" was derived from the word *fossus*, dug out, and that, therefore, every stone in the ground was really a fossil.

Mr. Goodman replied that it might be called so; but the term fossil is, for convenience, now limited to those organic remains which, plentifully distributed through the substance of the earth's crust, show how plants and animals abounded in former times,—from the reptile, which wallowed in mud and slime, to the delicate dragon-fly which sported over the brook.

Geologists have been for a long time occupying themselves with making out the order of creation from these remains,—which are of a low order in the earliest or lowest rocks, and rise in rank as they occupy later or higher strata: the first creatures, inhabiting the lowest and oldest rocks, being worms and trilobites and sea-weeds; then shellfish, of various kinds; then fish and land-plants; afterwards lizards and other reptiles; then birds; and, finally, great beasts, ending with their lord and master, man. But with the details of this fine order of the fossil world, which, in fact, have not even yet been all made out so as to settle disputed points, I will not perplex you, but will simply describe some of the more remarkable fossils of plants, shells and animals.

These remains, however, are not found in all rocks; for hitherto granite, trap, and other so-called igneous rocks, whether lying deep under ground or elevated to the tops of high mountains, have yielded no fossils. Limestone, slate and conglomerate contain many fossils; sandstone and clay abound with all sorts; coal-beds consist almost entirely of fossil vegetation; while chalk seems to be composed wholly of animal remains.

The study of these remains gives us the science of palæontology, so called from three Greek words, *palaia*, *onta*, *logos*,—meaning *ancient*, *things*, *talk*. Although the ancients noticed fossils, and the science has such an ancient name, it is a very modern part of human knowledge, having almost been begun by the great French savant, Baron Cuvier.

Alexander the Great sent the horns of a Scythian animal to Delphi, as a great curiosity; and tusks and bones of remarkable monsters were often hung in the temples of Rome; while Theophrastus, the pupil of Aristotle, collected petrifactions on the Getulian Mountains of Africa, which he considered the relics of Deucalion's Flood. Strabo, the ancient geographer, accounts for fossil sea-shells being found inland by supposing that the original ocean-bed had been elevated by earthquakes or volcanoes. Learned Arabs discussed the origin of fossils in the tenth century; but it excited no European interest till the Italians, in the sixteenth century, began to investigate the subject; and for three hundred years various theories were started. Some maintained that these remains were mere "sports of nature;"* others, that they were the "product of fatty matter fermented by heat," "earthy concretions," the "results of tumultuous movements of terrestrial exhalations;" or "products of the heavenly bodies." A few maintained, from the beginning of the inquiry, that they had all once belonged to living beings; but the kind of living beings was quite mistaken. A Swiss professor of anatomy pronounced the bones of an elephant to be those of a giant nineteen feet high; while in England similar fossils were actually once regarded as "the bones of the fallen angels." In Warwick Castle, a bone of a fossil mammoth is shown as one of the ribs of the Dun Cow of Guy, Earl of Warwick!

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* A book has even been lately published in New York, in which the author—strange to say, an educated man—maintains this absurd old notion.

Many fossils are very different from any species now existing, and very strange names and descriptions were applied to them. Some agates, mica-slate, and fibrous tremolite, were mistaken for petrified oak, maple, or hemlock; fossil stems and trunks of plants among coal were called rattlesnakes; certain shells were termed butternuts and walnuts. The people of Middle Pennsylvania call the spirifers and encrinites of the Devonian rocks of their neighbourhood beeves' hearts, butterflies, and Indian screws. Some varieties of polyparia are regarded as the horns of deer or petrified pork. Even petrified squaws, pappooses, and buffaloes were announced as existing in the Far West of America. The existence, however, on the earth's surface of remains of extinct animals in their natural state, is not a fiction. In the year 1801, the entire carcass of an enormous animal was discovered projecting from an ice-bank near the mouth of the river Lena, in Siberia. Two years afterwards the ice melted, so that the whole fell on to a sand-bank, where a drawing was made of it. The flesh was so firm and fresh that dogs feasted on it for two or three years; the skin was so thick and heavy as to require the united strength of ten men to remove it, and more than thirty pounds' weight of its hair and bristles were gathered up, of so thick and warm a nature as indicated its preparation for a cold climate. The tusks yielded good ivory. Indeed, notwithstanding this northern race of elephants has long been extinct, there is such an abundant supply of fossil elephants' tusks in Siberia, that though these "ivory quarries," as they have been appropriately termed, have been worked for more than a hundred years, great quantities are still annually imported into Liverpool, where they find a ready sale to comb-makers and other ivory-workers.

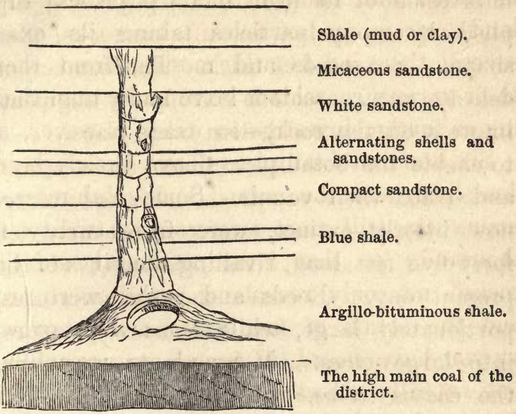
Alice asked if this could be accounted for, since the ivory Mr. Layard found at Nineveh seemed almost destroyed by time.

Mr. Goodman said, perhaps the heat of the climate of Nineveh promoted its decay. This Siberian fossil ivory comes from a region where cold arrests the decay of animal substances. But there may have been also a great difference in the length of time during which these several quantities of ivory have been where they are found.

Fossils are so plentiful everywhere that it is stated that two-thirds of the present dry land are composed of fossiliferous rocks, often several thousand feet thick. The number of their various contents is continually augmenting as further investigation takes place.

Six hundred fossil plants have already been described, and the animal and zoophyte remains are still more numerous,—nearly ten thousand; so that "the testimony of the rocks" not only reveals chemical mixtures, and the action of fire, water and pressure, as you have heard in former conversations, but actually shows us the forms and conditions of extinct vegetable and animal life, and explains how their death and decay are made subservient to the well-being of future generations. Very few of the species found fossil still survive.

Some of the most perfect fossil-plants, and of the largest size, are chiefly found among the coal-measures; but the old and new red sandstones, limestone, and clay are not destitute of them. The pines, or cone-bearing trees, are found as fossils in the rocks of all ages, back as far as the coal-era,—sometimes, as at Killingworth Colliery, Newcastle, rising through no less than seven different strata.


Shale (mud or clay).
Micaceous sandstone.
White sandstone.
Alternating shells and sandstones.
Compact sandstone.
Blue shale.
Argillo-bituminous shale.
The high main coal of the district.

Fossil tree at Killingworth Colliery, Newcastle, England. (See De La Beche, p. 503.)

In the lowest rocks most of the plants are sea-weeds. It might be thought that sea-weeds would have speedily decayed, most of them being soft and weak. Of course, many of them must have perished without leaving any traces; but the different conditions in which fossils are can be accounted for. While the hard bones themselves are sometimes preserved, the more porous substances have become filled with stony matter, or petrified; and sometimes the plant or animal itself gradually decayed, leaving only the impression of its form, or its place was supplied by stony particles taking its exact shape. Sea-weeds and mosses, from their delicate nature, seldom leave more than their impress on the rock,—so exact, however, as to enable the botanist to detect their species and trace their vessels. Some club-mosses, now utterly extinct, were from twenty to forty-five feet long, rivalling the pines of the present day. Reeds and rushes were proportionately large, while ferns were grown into large trees. Many plants resembling the cactus tribe, with large trunks, curiously fluted and scarred, called, from these circumstances, sigillaria and stigmaria, are met with, as well as the whorled leaves of other tribes, to which the name of asterophyllites is given.

When coal is laid for a time in acid, until all the soft parts are dissolved, the curious structure of the original plants out of which it was made can be seen in the microscope.

The actual cones or seeds of these plants are found occasionally in what are called the dirt-beds, or thin layers of vegetable mould, apparently composed of the decayed foliage of the trunks, which occur at intervals even amidst so hard a substance as the Portland stone. In the London blue clay upwards of seven hundred species of seeds and fruits have been detected,—most of which belong to a much hotter climate than that of the present age, fruits of the palm, gourd and melon tribes being distinctly visible, while laurels and custard-apple-trees, with others of the plane, buckthorn and hazel families, nearly resembling the present forests of the United States, flourished even in the latitude of London, where similar plants are now protected and cherished in the Crystal Palace as tender exotics.

The earliest animal fossils comprise many zoophytes and coral-workers. Some of these were small enough to construct those delicate little specimens which need the microscope to reveal their perfections. The encrinites, or stone lilies, when alive, must have waved like tulips, on long stalks of stony rings,—some numbering twenty-six thousand rings to a single individual. In their fossil state they compose masses a hundred feet thick, and are clearly visible in many marbles, and in blue limestone rocks. The single wheel-like bones of the stalk abound in the limestones of the coal-measures, especially in the great limestone of the lower coal-measures of Western Pennsylvania and Eastern Ohio. In the north of England, people call them St. Cuthbert's beads. Shells, both fresh-water and marine, are plentiful in rocks, not only far inland, but on the tops of high mountains. Some of them are so minute that forty-one thousand millions are calculated to be contained in a cubic inch; while others are found whose single diameters measure two or three feet.* The bivalve shells are as accurately fitted together as those of the present day.

The ammonites—so called from their curled-up appearance, resembling the coiled horn on the ancient statues of Jupiter Ammon—are very various in appearance and colour, but all contain a number of separate chambers, through which an air-tube passed to enable the creature which lived in the mouth of the shell to rise or sink at pleasure. Mathematical architects have pointed out the exquisite contrivance by which the shapes of these divisions have been diversified, so as to produce the great amount of strength requisite to prevent the sides of the shell from being crushed by the pressure of the water when the animal desired to be below the surface; and one consequence of this arrangement is to cover the outside of the shell with the most beautiful waved lines.

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* Professor Ehrenberg's estimate, from microscopic investigation. From stones in Tuscany, Soldain obtained chambered shells, like that of the nautilus, so small that one thousand of them weighed but a single grain.

The minute nummulite shell of the foraminifera of which the Pyrenees and some of the rocks in the Crimea and Egypt are composed, are similarly chambered. In the coarse limestone near Grignon, in France, no less than four hundred varieties of marine, land and fresh-water shells have been detected, all mingled together; while the stone called Paris miliolite is entirely composed of millions of tiny shells not larger than grains of fine sand, yet exhibiting various shapes;* while the larger kinds, if differing from our present shells, rival them in beauty, variety and perfection.

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* See Lyell's Manual, p. 194.

You may see that the shells in this group of fossils from Dudley are innumerable; and in this large slab of limestone from Nippenose Valley, near the Susquehanna River, the whole surface is covered with a colony of these nut-shaped shells, all lying as close as possible together, just as they lived and died in their native bed!

There are also many fossil crustaceous animals, such as the sepia, the remains of whose ink-bag have been found perfect enough to supply material with which to draw his own portrait; the trilobite, likewise, whose beautiful and complicated projecting eyes contained four hundred spherical lenses, placed on one side only.

The icthyosaurus, megalosaurus and plesiosaurus, remains of which are preserved in some museums, were enormous reptiles of the lizard tribe, the former thirty feet long, the latter twelve or fourteen feet; while the megalosaurus, or great lizard, sometimes measured forty or fifty feet. The pterodactyle, a lizard with bat-like wings, was also gigantic. Their teeth have been plentifully preserved, and indicate a capacity for tearing their prey: indeed, half-digested bones of small animals are often perceived within the cavity of the skeleton. The plesiosaurus himself seems, from these remains, to have been often the victim of his larger relatives.

These are from sandstone. Remains of immense animals of the frog kind occur also in these rocks. In the grounds of the Crystal Palace at London, Professor Owen has endeavoured to clothe all these ancient creatures in the forms it is supposed they wore during life. The form of an animal can be surmised with some accuracy from a part of its bony structure. Thus, it is found that the teeth are exactly suited for the particular sort of food the animal lived on, and that these teeth also correspond with the form of the creature, as feeding on animal or vegetable diet: so that some general idea may be obtained of its appearance. When the whole skeleton is preserved, there will be little difficulty.

The remains of a few fossil snakes have been discovered in some quite modern rocks, such as the London blue clay; and these are chiefly of the python and boa kind. They must have been about twelve or fifteen feet long. In the limestone rocks of Tonna, near

Gotha, in Saxony, fifteen feet deep, four snakes' eggs were found in 1850, surrounded with petrified leaves and quite enclosed in the stone. Many recent shells were there also; and the whole mass is comparatively modern.

In the celebrated lithographic stone of Solenhofen, in Bavaria, no less than two hundred and thirty-seven species of fossil animals occur, comprising pterodactyles, saurians, tortoises, fish, crustacea, and twenty-six insects. Footprints of wading-birds are also seen in sandstone; and lately the fossil bones and eggs of a gigantic bird—the dinornis—have been found in New Zealand, the skeletons of which stand nine feet high.

Fossil quadrupeds, or rather mammal animals, are seldom found with the reptiles, but become abundant in the formations near the surface of the ground; and, while they occur in all sorts and sizes, several are gigantic enough to rival the huge reptiles just described. The great mastodon of America is the largest whose fossil skeleton has yet been found complete: the lower jaw alone of one specimen weighed sixty-three pounds, and was two feet ten inches long. The mastodon had two ivory tusks, and seems to have been of the elephant tribe. The dinotherium was an amphibious monster, something between a whale and an elephant, standing on great columnar legs, with a body supposed to have been even forty-five feet long, and two tusks curved downward from the lower jaw, by which perhaps he anchored himself to the banks of the rivers or marshes in which he lived, while he munched the roots of the trees and the coarse reeds which grew upon the shore. The megatherium and megalonyx were animals of the sloth kind, with broad, flat, five-toed feet, and huge claws fitted for digging the roots for which their teeth seem best fitted. Mammoth bones abound all around the globe, in a broad belt extending from the fortieth to the seventeenth degree of north latitude.

In India huge fossil animals are found, of shapes so strange that there seems some excuse for the fables of animal feats in the Hindoo mythology. Many remains of tortoises especially have been discovered, whose shells are similar to those of the present day, except in size,—the carapace, or back-plate, alone measuring twenty feet.

Many other fossil mammals have been found, of the pig, camel, giraffe, horse, dog and opossum kind. In the Paris chalk-basin alone, twenty different kinds have been detected, many of which exactly correspond with fossils in the Himalaya Mountains of India. Judging from fossil remains, it might be difficult to find an age when creatures did not prey on each other.

Alice interrupted Mr. Goodman, and inquired if there are any fossil fishes.

Nearly nine hundred varieties, said Mr. Goodman, have already been described. Some are like those we know in the present day; others, differing in size and shape, occur in chalk, limestone, clay and coal. They are distinguished from each other by palæontologists chiefly by the kind of scales or skin they wore. Some—called placoidians, from the Greek word *plax*, a shield—are covered with bony plates, like the sharks and rays of the present time. The ganoidians—so named from the Greek word *ganos*, splendour—are clothed with brilliant scales, composed of bone without and enamel within, of various elegant shapes, arranged with perfect regularity, and are much more numerous as fossils than the living species, there being now, so far as we know, no other existing representative of them than the sturgeon, and the bony pike of North America.

Some of these fossil fish had strange-shaped heads: one, the cephalaspis, was finished off in sharp edges, like the horns of a crescent,—probably designed as weapons. The coccosteus had berry-like tubercles all over its plates; and seven species of pterichthys had wing-like appendages which might have served either for paddles or for defence. Some of these ganoids were so nearly allied to reptiles that they are termed sauroids, or lizard fish. The most remarkable is the megalichthys, or great fish, whose remains were first found near Edinburgh: it must have been a huge creature, for some of its scales are five inches in diameter, and one tooth alone measures five inches.

STING OF THE PLEURACANTHUS.

The largest fossil fishes occur in the coal-measures, where the teeth of the rhizodus are four times the size of those of the largest living crocodile;

but the sting of the pleuracanthus, a placoid fish, is one of the most singular weapons of the tribe. It is about fourteen inches long, sharp and polished as a stiletto, round and dense, so as to be of great strength. On two sides there were a thickly-set row of barbs, hooked downwards: so that it must have been an instrument not only of destruction, but of torture. Some of these fossil fishes, therefore, and reptiles, must have been formidable enemies to one another.

At Aix the chalk abounds with fishes thickly clustered together. It is estimated that the fossil-beds in Great Britain must be some miles thick. In Pennsylvania and Virginia the fossil rocks of the oldest date alone, the *palæozoic*, measure seven miles through. The rest may measure three miles more. In the Hastings sand, and Purbeck limestone, in Europe, there are strata one thousand feet thick, filled with the minute cases of the cypris. The coral crag of Berkshire consists of petrified coral, generally retaining the position in which they grew at the bottom of the ocean. In this a great variety of beautiful corals can be seen by the microscope.*

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* See Lyell's Manual, p. 262.

The coal-beds show how vast has been the accumulation of vegetable remains.

Alice asked how petrifaction is produced, and whether it takes a long time.

Mr. Goodman said, It goes on to some extent in the present day, as may be seen in Matlock, or Knaresborough, or Clermont, as I before described, or at Sharon Springs, or any other place where objects are continually exposed to streams of water containing a solution of stony or metallic matter, which gradually encrusts them. Clay containing sulphate of iron will in a few years, or even in a few months, produce a very perceptible change in a bone buried in it. Some springs hold iron in solution; and vegetable matter is in time changed into oxide of iron, as is often seen where bog-iron-ore is yearly deposited. Heat may promote a more rapid petrifaction; as Mr. Göppert placed fern-leaves carefully in clay, and then exposed for some time to a red heat,—when the leaves were made to resemble the petrified plants occuring in rocks.

Many bones and shells, however, remain unchanged in limestone, chalk, clay and sand, and may owe their petrifaction to seclusion from the action of the atmosphere, as is the

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case with those skeletons carefully enclosed in stone coffins found entire beneath the ruins of ancient abbeys and priories: they, however, speedily crumble into dust when once exposed to the air. Remains once covered by the eruption of volcanoes are, in like manner, preserved,—as was evident in the cities of Pompeii and Herculaneum, disentombed, in our own time, after eighteen centuries of burial. The bones found there were not petrified, I believe. Indeed, the cause of death must in many cases have been suffocation only, as the remains were found in cellars or dungeons quite free from the volcanic ashes which overwhelmed the city, but had not penetrated these apartments, though completely blocking them up.

In the fossil remains of rocks there is great variety in the aspect and position of the bones. Sometimes only a solitary skeleton is discovered, crushed and broken, as if it had died quietly and been disturbed by the weight of accumulated matter gradually pressing down upon it from above. In other cases there are whole beds of fossil fishes, or quadrupeds, in every variety of attitude and stage of petrifaction, as if they had been suddenly overwhelmed by some convulsion of nature. Caves forming the dens of wild beasts appear to have had their openings closed by the fall of adjacent rocks; and in them are found the bones not only of their owners, but the gnawed remains of their prey. At Kirkdale, twenty-five miles from York, there is a cave where the remains of three hundred hyenas were found, besides many others of the ox, rhinoceros, hippopotamus, horse, bear, wolf, hare, water-rat and several birds. Many of these latter bones appear to have been broken by the teeth of the hyenas: they are confusedly mixed in loam, or mud, and dispersed through a crust of stalagmite which now forms the floor of the cave.

The hippopotamus, rhinoceros and elephant are not English animals; nor are hyenas. The presence of these three hundred hyenas and their prey is, therefore, a curious and suggestive fact revealed by geological research. It can only be explained by supposing that the climates of the earth must have undergone great changes, and that the temperature of England must have been formerly much hotter than it is now.

Ossiferous breccias, or rocks composed of fragments of bone, cemented by some stony matter, occur in all parts of the globe. Those lately discovered in Australia closely resemble the bony breccia of the Mediterranean, in which the fragments are firmly bound together by a red ochrous cement. There are likewise, in various places, beds of fossil shells and corals, which seem to have been left by the receding sea or river floods. In Suffolk there are two distinct narrow beds of fossil shells and corals, extending for many miles,—one of which (called the coralline) is white, and the other red crag, but containing not less than five hundred and seventy-five varieties of testacea alone; about one hundred and fifty of these being equally common in both crags.

In the red crag, the whole mass, both of shells, sand and corals, is of a deep yellowish-red colour, from iron, or ochre, making part of its composition. The greater number of these fossils differ from any known species now existing. Similar fossils are found near Antwerp, and in Normandy.

Near the submerged forest on the coast of Norfolk, in England, elephants' grinders are found in such numbers that two thousand were dredged up by oyster-fishers in thirteen years. They call it the elephant-bed.

The blue marl at the foot of the Apennines is very aluminous and contains many fossils. Near the city of Parma, for the thickness of two thousand feet, it is full of small sea-shells, which are soft when first removed, but become hard when dry. The enamel is often well preserved, and even their external colour and pearly lustre, as well as the ligament uniting the valves, which is sometimes perfect. Occasionally, however, the shells are entirely silicified, or turned to flint.

The seven hills on which Rome stands are composed partly of marine shells, with coverings of volcanic tufa, and usually capped by deposits from rivers or lakes. But it is impossible to describe all the interesting phenomena which are continually being discovered as the surface of our earth is turned up for the railroads, canals and mines of its restless inhabitants. In passing through cuttings by rail or road, it is very interesting to observe the rocks on each side as they actually stand.

In sandstone there is often the ripple-mark existing, which we perceive on the shore of every calm sea or lake; and in the green slate of Cape Breton, Nova Scotia, rain-drops and worm-tracks are observed on successive layers, the upper one showing exact casts of the drops below. The sides of these are raised so as to indicate from which point of the compass the wind blew, making the rain to slant. Professor Hitchcock made clay into paste, and sprinkled water upon it, which produced exactly similar marks. Footmarks of the chirotherium have been observed among these ripple-marks.

Mr. Goodman observed the great interest of his young auditors in the objects and facts disclosed by the discoveries of geology in modern times. Thus he had been led to extend his remarks in this direction, and had turned their attention, without much of scientific order, to familiar and accessible subjects,—his view being rather to stimulate than to satisfy curiosity, and so to lead to future inquiry and study.

Having gone over most of the specimens collected in the "Friendship-Grotto," and various engagements being about to disperse several of the party usually gathered there, he congratulated them on the pleasant hours they had passed together, adding a hope that, if it were God's will, there might be more of such happy meetings in the same place.

As regarded the subjects latterly referred to, Mr. Goodman said that the discoveries made in the structure and arrangement of the earth's crust all tended to establish the great truth that every thing had been created, designed and arranged by the omnipotent and omniscient God for purposes of love and kindness to his creatures, and especially to man. All that is opened to our view delightfully confirms to our senses how great, how perfect and how good our God is. In the words of the prophet, we may say, "Hast thou not known? Hast thou not heard, that the everlasting God, the LORD, the Creator of the ends of the earth, fainteth not, neither is weary? There is no searching of his understanding." Isa. xl. 28.

But it is not in the earth's crust only that we are to note the wisdom and power of God. In that stone book we read of mighty revolutions in matter, and in the book of history the revolutions of mankind are related; but in the book of God we read of the revolutions of the human soul,—that it was created upright, to enjoy sacred and holy communion with its Creator; how, by disobedience to God's just commands, man lost his privileges, and became not only depraved himself, but spread depravity around: yet "God so loved the world" that he gave his Son to be a sacrifice, that men might be redeemed, and, by believing in Christ, might be pardoned and sanctified, to live forever; and when, at the last great day, these heavens shall pass away and this changing earth be burned up, those, his faithful servants and children, whose names are written in the Lamb's book of life, shall be raised from their long sleep of death and be presented faultless before the throne of God.

"Oh that, with yonder sacred throng,
We at his feet may fall,
Join in the everlasting song,
And crown him Lord of all!"

THE END.

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